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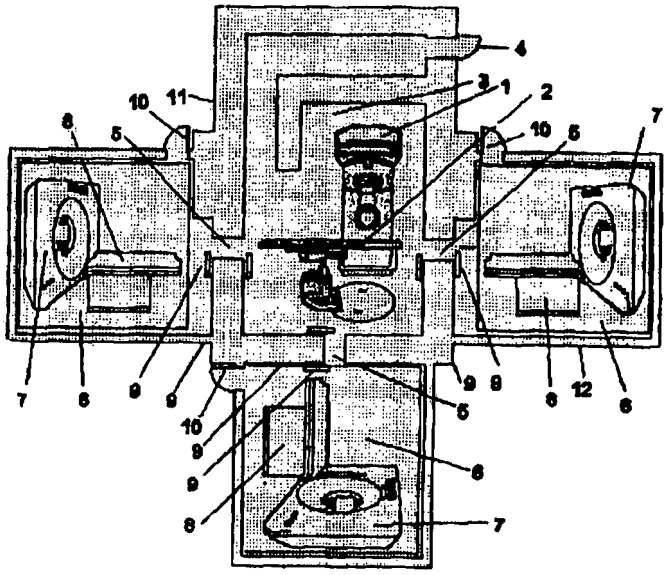
(54) Title: MEGAVOLTAGE RADIATION THERAPY MACHINE COMBINED WITH DIAGNOSTIC IMAGING DEVICES

(57) Abstract

The patient setup and treatment verification for radiation therapy are done with diagnostic imaging devices (7) which are connected to a room (3) containing a mega voltage radiation therapy machine (1). The diagnostic rooms (6), and the mega voltage therapy room (3) are connected to each other by openings (5) in the shared secondary wall of the accelerator room (3) or through an anteroom (109) to the mega voltage therapy room. Daily patient setup for routine and three-dimensional conformal radiation therapy and online treatment port verification with superimposed isodose are done with the patient on the diagnostic imaging table (8). The patients are transferred from the diagnostic table (8) to the treatment table (2) without changing the verified treatment position. The patient setup in diagnostic rooms (6) is caught up with the rapid turnover of patients in treatment room (3). The diagnostic devices are also used for routine diagnostic imaging.



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MEGAVOLTAGE RADIATION THERAPY MACHINE COMBINED WITH DIAGNOSTIC IMAGING DEVICES

DECRIPTION

TECHNICAL FIELD

This invention pertains to the medical megavoltage radiation therapy and diagnostic imaging.

BACKGROUND OF THE INVENTION

The present day radiation therapy for cancer is delivered mostly by megavoltage machines like the medical accelerators or by cobalt-60 units. Among the medical accelerators, linear accelerators are the most widely used system. A few other medical accelerator systems are also in use. They include the old Van de Graaff generator, the betatron and the microtron. Both the Van de Graaff and the betatron accelerators are technically inferior to cobalt-60 unit and to the widely used linear accelerators. The other modes of radiation therapy include the treatment with heavy particle beams such as neutrons, protons heavy ions and negative pions (Kahn, F. M., Clinical radiation generators, in The Physics of Radiation Therapy, 2nd ed., 49-70, 1994).

The cobalt-60 units are relatively cheaper to purchase and to maintain than the medical accelerators. Therefore, cobalt-60 machines are the most widely used treatment machines in countries where the purchase and maintenance costs are of major concern. The lower maintenance cost of the cobalt-60 unit is compensated by the every five year period replacement of the cobalt-60 source that is very costly. The other major disadvantages of the cobalt-60 machines include its low energy (1.33MV), high penumbra, higher skin dose, lower dose rate and the difficulties associated with the source handling. If the source is not replaced by the

scheduled time, it can result in very poor treatment. The partially decayed cobalt-60 source is an environmental hazard of greater magnitude. The cost of the environmental cleaning up of a partially decayed and mishandled cobalt-60 source was over 34 million dollars. There were many radiation associated tragic deaths including those innocent children who use to play at the dumping site of the cobalt-60 source. For these reasons, the World Health Organization is attempting to replace the present cobalt-60 units with more efficient medical accelerators (World Health Organization, Advisory Group Consultation on the Design for Megavoltage X-Ray Machines for Cancer Treatment in Developing Countries, 6-10 December 1993, Washington, D. C., publication pending).

The much higher cost of the medical accelerators both for its initial purchase and it's subsequent maintenance is a greater hindrance in it's widespread use especially in those countries with limited resources. A today's standard 6MV medical linear accelerator with its accessory systems could cost about $ 700,000 or more (Quotation: Varian Oncology Systems 1993, Philips Medical Systems 1993, Siemens Medical Systems 1993) The cost of an accelerator with 15-20 MV photons and varying energy electrons or a modern medical race track microtron could reach several millions. A modern cobalt-60 unit with higher source strength may cost to about $ 250,000 but when the accessories, the table and the cost of the source are all added together, its cost is about over $ 400,000 (Quotation: Theratronics 1993).

The computed tomography (CT) of the tumor bearing regions obtained with the aid of a diagnostic CT is generally used for treatment planning and dosimetric calculations. (Khan, F. M., Treatment planning II: Data, Corrections, and Setup; in The Physics of Radiation Therapy, 2nd ed., 260- 314, 1994) Since these CT are taken in a different department with a routine diagnostic CT, they are often not reproducible under the treatment conditions of a patient on the radiation therapy machine. This positioning error can cause significant error in radiation dose given to the tumor and to the surrounding normal tissue. In general fractionated radiation therapy is given as one treatment a day for about 30 to 35 treatments to a patient. The difficulties associated with the day to day identical treatment positioning of a patient on the treatment table as the initial dosimetric planning made with the aid of the initial simulation and the diagnostic CT taken elsewhere increases the cumulative dosimetric error both to the normal and the tumor tissue.

Varying methods for aligning the patient to the intended region of treatment and surgery has been developed but in those methods the patients are positioned on the diagnostic imaging table for the initial planning and days after the planning is completed, attempts are made to reposition the patient on the radiation therapy machine's table in an identical manner as the patient was on the diagnostic imaging table before (Miller, D. W.; Patient alignment system and procedure for

radiation treatment; US Patent 5,117,829., 1992; Miller, D. W., Method of assembly and whole body, patient positioning and repositioning support for use in radiation beam therapy systems; US Patent 4,905,267; Klausz, R., Method of controlling the positioning of a patient with respect to an X-ray device and installation for carrying out such method; US Patent 4,633,494) The days later reproducibility of patient's positioning as was on the diagnostic imaging table before is difficult and often can be inaccurate. During the course of several weeks of treatment, the patient's contour can significantly change causing the initial planning and the patient's fitting position in an immobilizing device increasingly inaccurate. In this invention, the patient's treatment setup is daily verified with the diagnostic imaging device and the patient is transported in this verified position from the diagnostic table to the treatment table of the megavoltage treatment machine.

Simulators equipped with CT are available to increase the accuracy of the treatment planning (Kahn, F. M., Treatment simulation; in The Physics of Radiation Therapy, 2nd ed., 277, 1994).The cost of such a modern simulator will exceed the cost of a medium energy medical linear accelerator. (Varian Ximatron/CT Option, quotation by Varian Oncology Systems; received in 1993). Therefore, the CT equipped simulators are not frequently used in most radiation therapy departments An other recent advancement in Radiation Oncology is the introduction of the CT-based simulator. In this system, a commercial CT is equipped with computer controlled laser drawing device and creation of digital reconstructed radiographs are used. The laser drawing is used to transfer the CT simulation to the patient for the appropriate patient's skin markings. (Ragan D. P., et. al., Clinical results of computerized tomography-based simulation with laser patient marking; in Int. J. Radiation Oncology Biol. Phys., 34: 691-695, 1996; Advanced Planning System for Radiation Oncology, advertisement by Siemens Medical Systems, Inc., received in 1996; Virtual Simulation System and Conformal Field Projector for Radiation Oncology, advertisement by Siemens Medical Systems, Inc., received in 1996; GE Advantage SIM CT Simulation in 3D, advertisement by GE Medical Systems, received in 1996) Again this is very costly. Moreover all these systems cannot reproduce the daily treatment setup on the treatment table as in the case of this invention.

In an effort to minimize the daily patient setup error, weekly port verification films with the patient on the treatment table in treatment position is taken with the high energy beams of the treatment machines (Kahn, F. M., Treatment verification; in Physics of Radiation Therapy, 2nd ed., 277-281, 1994). Because of the compton effect of the megavoltage beam the image quality of the port film is poor than the conventional x-ray films. To make the necessary adjustments, the port film has to be reviewed while the patient is still on the accelerating table and in the treatment

position. The time needed to develop each port film taken keeps the patient for longer time on the treatment table. It can be very uncomfortable to the patient. It also reduces the efficient use of the accelerator time. In the process of taking a port film, usually a 0.004-0.007 cGy exposure is made to the intended treatment region and on top of it a wider full field 0.002-0.004 cGy exposure is also made. The second exposure is made to assist the anatomic interpretation of the region of interest. This exposes a wider anatomic region to the high energy radiation than the intended tumor bearing treatment area. It is not practical to take daily treatment verification films. Therefore, a compromise is made by making the treatment port verification only once a week. The developing electronic portal imaging devises (Lam, W.C.; On-line treatment monitoring for radiation therapy; US Patent 4,365,341, 1982; Kahn, F. M., Electronic Portal Imaging, in The Physics of Radiation Therapy, 2nd ed. 278-279, 1994) are costly and it also do not give the diagnostic x-ray quality images.

3D localization of the tumor and the critical normal structures used in the CT aided 3D conformal radiation therapy planning for stereotactic radiosurgery(Brunnett, K. J., Computer assisted stereotactic surgery system and method; US Patent 4,791,934, 1988; Kooy, H. M., et al., Treatment planning for stereotactic radiosurgery of intra-cranial-leasions; in Int. J. Radiation Oncology Biol. Phys., 21: 683-693, 1991) and treatment of the paranasal, (Hirohiko, T., et. al., The value of treatment planning using CT and immobilizing shell in radiotherapy for paranasal sinus carcinomas; in Int. J. Radiation Oncology Biol. Phys. 16: 1989) chest (Sibley, G. S., et al. The treatment of stage III non-small cell lung cancer using high dose conformal radiotherapy, in Int. J. Radiation Oncology Biol. Phys., 33: 1001-1007, 1995) and other tumor sites (Vijayakumar, S., et al., Implementation of three dimensional conformal radiation therapy: prospects, opportunities, and challenges; in Int. J. Radiation Oncology Biol. Phys., 33: 979-983, 1995) can be improved by pre-treatment port verification with a CT and subsequent transport of the patient from the CT table to the accelerator table without changing the patients positioning. It facilitates reproducible treatment setup as is done with the CT. The rapid increase of the 3DCRT has rendered improved control of tumor growth, long term survival and reduced complication of radiation therapy. The present widely used two-dimensional radiation therapy planning (2D) often underestimates the gross tumor volume and hence the chances for missing part of the tumor in the treatment field or its inadequate dosage. The conventional transverse CT display format is not an ideal display of the anatomic relation to the radiation beam as usually used in a treatment settings. The path of the radiation beam that is not in perpendicular to the axis of the transverse CT slice is difficult to visualize. In the 2D planning the isodose is displayed in multiple CT slices which also makes it difficult to compare the best treatment plan. The conventional transverse CT

fails to confirm the continuity of a radioactive seed used in the brachytherapy from one CT slice to the next one. The 3D volume rendering as used in the 3DCRT overcomes these shortcomings of the 2D (Roseman, J. et. al., Three- dimensional display techniques in radiation therapy treatment planning; in Int. J. Radiation Oncology Biol. Phys., 16: 263-269, 1989) However when the volume rendering 3DCRT is done with the patient on the CT table at a distant and different setup Diagnostic Radiology Department than the actual treatment delivered with the patient on the treatment table of a Radiation Oncology Department, many of these advantageous of the 3DCRT are lost because of the difficulties associated with the reproducibility of the patient's setups at one department to the other.

The stereotactic radiosurgery of intracranial tumors and vascular malformations needs precise and reproducible volume rendering 3DCRT planning. At a Radiation Oncology Department where many stereotactic radiosurgeries are done, the weekly number of such procedures is limited to about four patients. It is because of the a waiting for access to an accelerator, delay in CT data transfer from the Radiology department to the Radiation Oncology department for treatment planning and the subsequent efforts to set up the patient on the accelerator table identically as the CT images was obtained at the Radiology department's CT. Excluding the waiting time for the access to the accelerator, the present turn-around time for the stereotactic radiosurgery is about four hours (Kooy, H. M., et. al., Treatment planning for stereotactic radiosurgery of intra-cranial lesions; in Int. J. Radiation Oncology Biol. Phys. 21: 683- 693, 1991).

This invention overcomes the above difficulties. After the daily on-line isodose superimposed treatment port verification by the diagnostic imaging device, the patient is transported directly from the diagnostic imaging device's table to the megavoltage radiation therapy machine's table. From the CT table the flat table top with the patient is rolled on to an extension table. The extension table with the flat table top insert and the patient is rolled on rails to the connecting accelerator room. The patient is transferred to the accelerator table by rolling the flat table top insert with the patient to the accelerator table. In this case, after the setup and verification of a patient's treatment on the diagnostic imaging table, the patient does not change the verified setup for treatment. In contrast to this, the present practice is to hope for identical positioning of the patient using markings made on the skin during the simulation with the x-ray simulator. With the present practice of CT imaging at the Diagnostic Radiology Department and delivery of the radiation therapy at a distant Department of Radiation Oncology, it is difficult to reproduce the initial treatment setup at the Department of Radiation Oncology with its megavoltage radiation therapy machine or by the simulator. Moreover during the course of six weeks conventional

radiotherapy, there will be physical changes in a patient to make the initial skin markings more and more inaccurate. The significance of this invention's patient transport from the diagnostic imaging table to the treatment table directly with the daily on-line treatment port verification to improve the quality of the treatment is obvious.

Radiation therapy is the most cost effective treatment for cancer in most developing countries. When diagnosis of cancer is made too late, the surgical treatment is not successful. Chemotherapy is very expensive and is often not well tolerated. By year 2015, about 9 million new cancer cases are expected per year in the developing countries of the world. There are not many medical accelerators in developing countries. (World Health Organization, Advisory Group Consultation on the Design for Megavoltage X-Ray Machines for Cancer Treatment in Developing Countries, 6-10 December 1993, Washington, D. C., publication pending). There is also a great shortage of modern diagnostic devices in the developing countries. This shortage will be even higher in the future if no innovative developments are made. Presently, most patients are treated with antiquated old cobalt-60 machines. This is associated with the prohibitive cost of medical accelerators and the modern diagnostic devices. The need to treat as many patients as possible every day with any available megavoltage machine makes the quality and precision of the treatment to suffer. Therefore, there is an acute need for more cost effective and high quality medical accelerators, diagnostic devices and its ancillary machines for delivery of today's standard diagnostic radiology and radiation therapy in the developing countries. This invention's efficient utilization of a megavoltage machine to treat three to four times the number of patients treated as now and the shared use of diagnostic imaging devices for diagnostic radiology and radiation therapy brings the cost-effective most modern diagnosis and treatment to the developing countries as well.

The megavoltage radiation therapy machine described in this invention can any of the presently used megavoltage radiation therapy machines including the accelerators or even a cobalt 60 machine. However the disadvantages of the cobalt 60 machine has been described earlier. Among the accelerators, the medical linear accelerators are the most commonly used ones at the present. In the following descriptions, the word accelerator is used as synonymous to any megavoltage radiation therapy machines.

Any of the commonly used imaging devices can be used for patient setup and verification. In the following examples, the CT combined accelerator is described, but the CT can be replaced with any other appropriate diagnostic imaging devices. The diagnostic imaging techniques using the magnetic resonance imaging (MRI), ultrasonic tomograms, transverse tomographic x-rays or any other similar imaging devises can also be used in place of the CT. The advantages of the

MRI and ultrasonic tomograms include no ionizing radiation is used for imaging. In these cases, instead of the CT, an other imaging devise is placed in the rooms adjacent to the accelerator. There are both advantages and disadvantages for these other imaging devises. The MRI allows a better imaging of soft tissue but it cannot image bone or calcifications. Additional difficulties associated with MRI is the magnetic interference with the metallic objects and the smaller hole of the MRI scanner. Since the megavoltage room and the MRI rooms in this invention are separated from each other, the interference from the metallic objects used in radiation therapy in the megavoltage room is avoided. The drawings shown in the diagnostic room can either be a CT or an MRI. The image quality of the ultrasonic tomogram is poor than that of the CT and the MRI, but it is much cheaper. It also provides a real time information that is extremely useful in the rapid set up of patients for treatment. Because of its smaller size and the real-time scan capability of the ultrasound, it can also be used as an added devise within the accelerator room itself for the rapid treatment setup verification of a patient on the accelerator table. The transverse tomogram have poor contrast and spatial resolution. It can also produce artifacts that could interfere with the dosimetric calculations. (Khan, F. M., Treatment planning II: Data, Corrections, and Setup; in The Physics of Radiation Therapy, 2nd ed., 260- 314, 1994) The use of the word CT in the following descriptions is synonymous to any of the above commonly used diagnostic devices.

The words CT and accelerator is used as an abbreviation for the various diagnostic devices and the megavoltage radiation therapy machines within the contest of their interrelations described in this invention. The CT and the MRI are the most commonly used diagnostic devices for radiation therapy planning. The linear accelerator is the most commonly used megavoltage radiation therapy machine.

An other major advantage of this invention is the dual usage of the diagnostic device. The diagnostic device (CT) when not in use with the megavoltage radiation therapy machine (accelerator) it is also used as stand alone diagnostic CT of a Radiology Department. This enhances the cost-efficiency of this system and the cooperative working environment of the Departments of Diagnostic Radiology and the Radiation Oncology.

DESCRIPTION OF THE DRAWINGS

Referring to the drawing shown in FIG. 1, numeral 1 designates a commercially available medical accelerator and its treatment table 2. It is housed in the accelerator room 3 which is constructed with required thickness radiation shielding material. The accelerator room has its entrance door 4, and wall openings 5, through which it is connected to the adjacent CT rooms 6, each containing a commercially available CT 7, and its table 8.The connecting wall openings between the accelerator room and the CT rooms are opened and closed with sliding shield doors

9. Both sides of the each wall openings are fitted with a sliding shield doors 9.These sliding shield doors are made of required thickness radiation protective material of a suitable kind. Doors 10, are for entrance to and exit from the CT rooms. The accelerator room's shielding walls 11 and the CT room's shielding walls 12 are constructed with the appropriate thickness shielding material based upon the photon beams energy. Since the accelerator's photon beam is in the range of MeV and the CT's photon beam is in the range of KeV, the accelerator's walls 11, has much higher wall thickness than the CT room's walls 12.

In FIG. 2, a commercially available CT's integration for its use with the accelerator is shown. The commercial CT table's cradle 13, moves forward towards the gantry's central opening 14, and backward on its intermediate support 15. Commonly a flat table top insert 16, for placement of a patient on a flat surface on top of the CT table's cradle 13, for radiation therapy planning CT scans is used. It is to reproduce the same outlines of a patient's body contour as the one that would result when the patient is placed on the flat table top of an accelerator table. In this invention, this table top insert is modified as identical to the table top of an accelerator table 17, and is used a common table top for the accelerator and the CT tables. A gantry 18, with its central opening's 14, diameter of about 70 cms is generally used for a radiation therapy planning CT. It is to accommodate both the patient and the devises used for the patient's settings for radiation therapy. Also shown in this FIG. 2, are the opened and closed wall opening with the modified table top insert 17, extended through the wall opening 5, towards the accelerator room and the closed wall opening without the table top insert 17, on the CT table's cradle 13, to indicate the modified table top 17 is completely moved to the accelerator room. The shield door is slid away 9a, from the wall opening for the passage of the modified table top insert 17 through it in one instance and as slid to cover the wall opening 9b, after the completion of the passage of the modified table top insert 17, from the CT room to the accelerator room.

In FIG. 3, the sectional view of the CT table with the modified flat table top insert 17, and the CT table's cradle 13, and intermediate support 15, with their cross sectional view through plane A-A are shown. Like a commercial accelerator's table top, the modified table top insert 17 has portions for mylar insert 19, a wood top 20, a tennis racket opening 21 and its non-metallic frame 22.The table top insert 17, the cradle 13 and the intermediate support 15, rests on the top of the table elevator and base assembly 23. The bottom of the modified table top's frame 22, is fitted with two sets of rollers 24, for its guided movement on the CT and the accelerator tables. The cradle's both lateral top surface is modified by attaching to it with two longitudinal non-metallic guide groves 25, on which the rollers 24, of the modified table top insert 17 can travel. The fitting of the longitudinal guide grooves with the cradle is further illustrated in FIG. 5, 6,7

and 8. At the end of the CT table cradle 13, two female notches 26, are fitted for connection with the extension table. The sections of the sets of rollers 24, of the modified table top insert 17, and its tennis racket 21, the guide groves 25, and the female notches 26 of the cradle, the intermediate support 15, and the elevator and base assembly of the CT table 23 are shown in the cross sectional view of the CT table at A-A plain.

FIG. 4 illustrates the sectional view of the modified flat table top insert 17, with a modified accelerator table and their cross section through the plain B-B. The accelerator table's top most portion where the patient is placed for treatment is removed and replaced with the traveling modified table top insert 17, which has the identical structural components as the usual accelerator table top, such as the mylar 19, wood 20, tennis racket 21, and the non-metallic frame 22, but it is also fitted with rollers 24, underneath it for its travel from the CT table to the accelerator table and visa versa. Like the CT table, the commercial accelerator table also has a cradle 27, and an intermediate support 28, but with a slightly different configuration. After removing the commercial accelerator table top's mylar wood and the tennis racket, its two side rails 29, are exposed and on which two frames 30 with side grooves 31, are fitted for the travel of the rollers 24, of the modified table top insert 17. The grooves on this frame and those fitted on to the CT table's cradle are aligned to make it as a continuos path for the smooth travel of the rollers 24, of the modified table top insert 17. It is further illustrated in FIG. 8. At the backward end of the accelerator table's cradle, two male notches 32, are fitted for its connection with the backward end of the CT table's cradle 13. The accelerator table's cradle 27, and the intermediate support 28, rests on its elevator and base assembly 33.

The cross sectional views at plain B-B through the modified table top insertion 17, accelerator cradle 27, intermediate support 28 and the elevator and base assembly 33 are also shown in this FIG. 4. In this cross sectional view, the modified table top insert 17, with the mylar 19, and its rollers 24, as aligned to the grooves 31, of the frame 30, that is fitted to the accelerator cradle's side rails 29 and the accelerator table's elevator and base assembly 33 are illustrated.

The sectional drawings in FIG. 5, the prefabricated track insert 34, and flange 35, with grooves 25, for the modified flat table top insert's 17, rollers 24, to travel on the CT table's cradle 13, its fitting to the cradle's existing fastener site 36, and the so established continuos grooves 25, on CT table's cradle 13, are shown. The existing fastener site 36, and its wedge like flange 37, on the CT table's cradle 13 is generally used to insert fasteners to its slot 38, for the secure positioning of a patient on the cradle. The fastener is attached to the hollow under surface created by the wedge like flange 37, of the fastener site. In this case, the slot 38, is made to

accept a similar but reversed flange 35, from the prefabricated track insert 34.The arrow at the top of the FIG. 5 indicates the direction by which the prefabricated track insert 34, is fitted to the existing fastener site 36, of the CT table's cradle 13. In the separate sectional drawing in the middle of FIG. 5, the completed assembly of the prefabricated track insert 34, with the preexisting fastener site 36, at the CT table's cradle is shown. The reversed flange 35, of the prefabricated track insert is brought underneath the flange 37 of the CT cradle's existing fastener site 36, and is firmly fitted together. Fastening of a longitudinal prefabricated track insert to the CT cradle's existing longitudinal fastener site 36, creates a continues groove 25, on top of the CT cradle. It is further illustrated in FIG. 6. A pair of continuos grooves 25, so made and secured with screws 39, on to the CT cradle's both lateral elevations are illustrated at the bottom of the FIG. 5's drawing. The female notches 26, at the end of the CT cradle for connection with the table extension are also shown here. The CT cradle's backward end 44, and its relation with other connecting tables to make a continuous connection from the CT table to the accelerator table is described under the FIG. 7.

In FIG. 6, the top longitudinal view of the CT table's cradle 13, with its existing fastener sites 36, on both of its lateral sides is shown. The modified flat table top insert 17 which sits on top of the cradle is removed to illustrate this longitudinal top view of the CT table's cradle. The arrows on both sides of the cradle indicates the longitudinal prefabricated track insert 34, as aligned for insertion into its existing fastener site's slots 36 to establish the continuos longitudinal grooves 25,on top of the CT cradle for the modified flat table top insert's 17, roller's 24, forward and backward travel. The configuration of these grooves 25, on top of the CT cradle 13, is further illustrated in the sectional drawing at the bottom of the FIG. 5.

FIG. 7 illustrates a table top extension 40, on top of an extension table 41, placed in the CT room as a means to create an extension of the CT table towards the accelerator room through the wall opening. Its forward end 42, is fitted with two male notches 43, which are identical to the accelerator table's cradle end's male notches 32, (FIG. 4 and 8). It connects with the corresponding female notches 26, at the backward longitudinal end 44, of the CT cradle. These connecting notches are brought in alignment and fastened with the female notches 26, at the backward end 44, of the CT table's cradle. Both table ends are further firmly attached with a latching clip 45, at the under surface of the table extension and with the clip fastener 46, at the CT cradle's under surface. The other end of this table extension 47, can reach the center of the wall opening 5. This end 47, of the table extension is fitted with two female notches 26, and a clip fastener 46, which are identical to those at the CT cradle's connecting end, 44. This end 47, can be connected to the two male notches 43, from the backward end 48, of an extension table from

the accelerator room. These male notches are identical to the male notches 43, of the extension table in the CT room and the accelerator cradle's backward end's male notches. All these male notches are identified by the numeral 43. After the connection with the backward end of the extension table from the accelerator room 48, with the backward end of the extension table from the CT room 47, they are firmly fastened with a latching clip 45, at the backward end of the extension table from the accelerator room and by the clip fastener 46, at the backward end of the extension table from the CT room. The latching clips 45, and the clip fasteners 46, are identical for the extension tables, accelerator cradle's end and the CT tables cradle end and hence they are identified by the same numeral 45 for the latching clip and 46 for the clip fastener. Both table top extensions are brought to the center of the wall opening 5, for this firm connection with each other. The opposite end 49, of the table extension from the accelerator room facing the cradle end of the accelerator table with its female notches 26, and the clip fastener 46, is similarly connected with the backward end 50, of the accelerator table's cradle by attaching the accelerator table end's male notches 32, with the female notches 26 of the extension table's end 49,and fastening them together with the latching clip 45, and the clip fastener 46. The projecting male notches 32 and 43, of the table ends, 50 and 42, are slid back when tables are not connected and pushed forward when these table end's connections are needed. These connections and fastening of the extension table from the CT room with the CT cradle on one side and with the extension table from the accelerator room with the extension table from the CT room through the wall opening and its final connection with the accelerator table's cradle end in the accelerator room on the other side provides the continuity of the table from the CT table's cradle to the accelerator table's cradle. This facilitates the establishment of the continuos grooves 25, from the CT cradle 13, in the CT room to the accelerator cradle 27, in the accelerator room (FIG. 8). The flat table top extension 17 can be rolled towards the accelerator room or to the CT room over these continuos longitudinal grooves 25 which is now connected with the CT cradle and to the accelerator cradle through the wall opening (FIG. 9 and 10). After a patient on the modified flat table top insert 17, is rolled from the CT cradle in the CT room to the accelerator cradle in the accelerator room through the wall opening 5, the extension tables are disconnected from each other and from the CT cradle and the accelerator cradle and they are moved away from the wall opening. The sliding shield doors 9, one at the side of the accelerator room and the other at the side of the CT room are moved to close the wall opening from both sides as in FIG.2, 9b.

FIG. 8 is an illustration of the commercially available accelerator table's cradle's backward end's 50, modifications for its connection with either an extension table's female notches 26, or with the CT cradle's backward end 44. It is fitted with two frames 30, on top of its each side

rails 29 of the accelerator table's cradle, 27. These frames contains grooves 31, which are symmetrical to the CT table's prefabricated track insert's 34, groove 25, (FIG.5). The modified flat table top insert 17, travels on the grooves 25, of the CT table's cradle 13, and on the grooves 31 of the accelerator table's cradle, 27. Symmetry of these grooves enables the flat table top insert, 17 to travel on top of both these tables smoothly. The sectional view of the CT cradle's backward end 44, with the prefabricated track 25, firmly attracted to it is also shown in the middle drawings of this figure and in FIG. 5. It's side by side illustration with the accelerator cradle's modified backward end 50, or to one end of the extension table is to demonstrate their connections to each other as shown in the bottom drawings in this FIG 8. In the bottom sectional view, the completed connection with the CT and the accelerator tables cradles or one of the cradle with one end of the extension table is shown. In this illustration, the modified accelerator cradle's 27, end 50, with the male connectors 32, is attached to the CT cradle 13, female notches 26. These table ends are firmly fastened together with the latching clip 45, and the clip fastener 46, (FIG. 7). After these connections, the accelerator table's side grooves 31,on its frame 30, becomes as a continuos groove with the CT cradle's 13, side grooves 25.

In FIG. 9, the patient transport from the CT table in the CT room to the accelerator table in the accelerator table is illustrated. The modified flat table top insert 17 is fitted with a head holder 51, and is shown as resting on the CT cradle 13. It is slightly advanced towards the wall opening and the accelerator table 2. For illustration, this initial position is indicated as 52, in the top drawing. In the drawing in the middle, the flat table top insert on CT cradle is rolled further towards the wall opening and the accelerator table 2, and brought at position 53. This continuos forward advancement of the modified flat table top insert towards the wall opening 5, and the accelerator table 2, is further illustrated in the bottom drawing with passage of the flat table top insert through the wall opening 5, reaching the accelerator table and continuing its forward advancement over the accelerator table's cradle 27. It is thus brought at about the half way over the accelerator cradle at position 54.

The FIG. 10 demonstrates the continuos forward advancement of the flat table top insert 17 over the accelerator table's cradle on the grooves 25, of the CT cradle and 31, of the accelerator cradle. as in the top and the middle drawings. In the middle drawings, the flat table top insert is transferred completely to the accelerator table 55. Afterwards, a 180 degree accelerator table rotation is made to bring a patient's upper portion of the body with the head holder 51, directly under the accelerator's treatment head if this region is to be treated. The arrow 56, indicates the 180 degree rotation of the accelerator table. In the bottom drawing, the flat table top insert 17, with the head holder 51, after the table's 180 degree rotation is shown. After the 180 degree

rotation of the accelerator table, the head holder 51 is brought at the opposite end of the accelerator table as in this bottom drawings. The wall opening and the CT in the opposite CT room is also shown. The FIG. 9 and 10 thus shows a patient's continuos transport form the CT table to the accelerator table and the subsequent rotation of the accelerator table to bring the patient at the desired treatment position without the patient's movement. In between the CT table and the accelerator table, the extension tables are placed as needed. It is illustrated in FIG. 7. In these descriptions, the movements of the flat table top insert 17, on the grooves of the CT cradle 13, extension tables 41, and on the accelerator cradle 27, are synonymous to the transport of a patient on top of the flat table top insert 17. For patients whose setup and verifications were done with the CT placed at 90 and 270 degree angles to the accelerator, only a 90 degree rotation of the accelerator table is required to bring the patient under the accelerator's treatment head.

FIG. 11 shows the longitudinal views of the CT and the accelerator tables with the modified flat table top insert on top of them. The both tables are modified for the travel of the modified flat table top insert's 17, rollers 24, over the grooves 25 of the CT cradle 13, and grooves 31, of the accelerator cradle 27. The modified table top insert's mylar 19,wood top 20, tennis racket 21, and its non metallic frame 22 are identical to those of a commercial accelerator's table top on which the patients are placed for treatment. At the backward end of the CT cradle, two female notches 26, for connection with the accelerator table's cradle is also shown. The CT table's intermediate support 15, cradle 13, and the modified flat table top support rests on the elevator and base assembly 23, of the of the CT table.

The bottom drawing in FIG. 11 is the modified accelerator table with the modified flat table top insert 17, on top of it. The regions of this modified table top insert, the mylar 19, wood 20, tennis racket 21, frame 22, the rollers underneath it 24, are all identical to the flat table top insert 17, on top of the CT table. The grooves 31, on accelerator table's cradle 27, is symmetrical to the grooves 25, on the CT tables cradle 13. The accelerator cradle's 27, side rails 29, are fitted with the frame 30, with its grooves 31, on which the rollers 24 of the modified flat table top insert 17, can be rolled to the CT cradle or visa versa. The accelerator table's intermediate assembly 28, the cradle 27, and the modified flat table top insert 17, rests on the accelerator table's elevator and base assembly 33.

FIG. 12 is an illustration of an other arrangement of the CT and the accelerator to enable the treatment of a patient without rotating the table in one instance and with table rotation in another instance. In first instance, the CT facing directly opposite to the accelerator's gantry 57, is placed in the CT room with the back side of the CT gantry 58, facing the wall opening 5. It is aligned

with the wall opening for the forward transport of a patient on the modified flat table top insert through the CT's central opening and the wall opening to the accelerator table. As described earlier, an extension table 41, can be placed in between the CT's central opening's back side 59, and the wall opening 5. In the accelerator room, a similar extension table can be placed in between the wall opening and the accelerator table. With this arrangement a patient is first setup on the CT table and after the treatment port verification with the CT, the patient is advanced forward through the CT's central opening's back side 59, and through the wall opening 5, to the accelerator room and to the accelerator table and placed directly under the accelerator's treatment head without a 180 degree rotation. If the CT is placed with its gantry's front facing the accelerator directly as shown in FIG. 1 and 14, and the patient's head is placed on the CT table with the head closer to the gantry and the foot at the backward end of the CT cradle, the accelerator table needs to be rotated to 180 degree after the patient is transferred to the accelerator room to bring the patient's head region under the accelerator's treatment head. It is described under FIG.10. A patient if placed on a commercially available CT table with the foot at the gantry end and the head at the table's backward end, the CT of the head and the upper portions of the body can also be done. For this, a three foot extension to the forward end of the CT cradle may be needed. By doing so, portions of the head may not be in the CT plane. This is a major disadvantage, particularly for head and neck region's treatment. The straight transport of the patient either by reverse positioning of the patient with the foot facing the gantry or by reverse positioning of the CT with the back of the CT gantry's central opening 59, facing the accelerator and moving the patient through the CT's back central opening to bring the patient's treatment region under the accelerator's treatment head eliminates the need for the accelerator table's rotation. This elimination of the table rotation further enhances the quality of conformal radiation therapy and the stereotactic radiosurgery. However as noted above, the reverse positioning of the patient with the head away from the CT's gantry may not be suitable for this kind of treatment to the head and neck region. The CTs positioned at 90 and 270 degree to the accelerator as in the second instance, will function as a combined unit with the accelerator by rotating the accelerator table to 90 degree to bring the patient under the accelerator's treatment head.. The numerals identifying the rest of the components in this FIG. 12 are as in FIG.1.

FIG. 13 further illustrates the direct transport of the modified flat table top insert 17, from the CT cradle 13, towards the accelerator table's cradle 27, through the CT gantry's central opening's front 14, and its back 59, and wall opening 5. The table top insert is rolled over to the accelerator table's cradle 27. In this instance, no 180 degree rotation of the accelerator table is made to bring the patient's treatment site under the accelerator's treatment head as in FIG. 10. If

the CT facing directly opposite to the accelerator is placed with the front of the gantry facing the accelerator (FIG. 1, 14) and the patient is placed in the usual manner with the head in the head holder which is closer to the gantry and the foot at the backward end of the CT table, then a 180 degree rotation of the accelerator table is required to bring the patient's head with the head holder 48, under the accelerator's treatment head. With the presently available commercial CTs, a reverse patient's setup on CT table with the patient's head away from the gantry's central opening is impractical since the difficulties associated with the geometrical positioning of the head for its satisfactory scanning. In this position however the scanning of the upper portions of the body can be done by attaching an extension of about three foot to the CT cradle's forward end and placing the patient in a manner to make use of this table extension. By doing so, a patient after setup and scan can be transferred to the accelerator table and brought under the accelerator's treatment head without the accelerator table's rotation. In contrast to this direct transport of the modified flat table top insert 17, towards the accelerator's treatment head, the bottom drawings shows a 90 degree rotation 60, of the accelerator table to bring the patient under the accelerator's treatment head when the CTs are placed at 90 or 270 degree(FIG. 1, 12, 14) to the accelerator. For critical procedures such as the conformal radiation therapy and the stereotactic radiosurgery, the ability to bring the patient's treatment site without this rotation is an added advantage for precise patients positioning and the delivery of the planned treatment precisely.

The configuration as in FIG. 14, with two accelerators, 1, and 61, and two CTs 7, and the CT tables 8, with the respective openings 5, in the walls for transport of the modified flat table top insert 17, with the patient's head holder 51, the accelerator tables 2, and the sliding shield doors 9, facilitates the routine daily radiation therapy with one accelerator 1, and the specialized treatment such as the stereotactic radiosurgery with other accelerator 61. In this case, the second accelerator 61 can be used as a dedicated one for special procedures such as the stereotactic radiosurgery, intraoperative radiation therapy and conformal 3D radiation therapy. After the setup and verification of a patient on the CT table, the patient can be transferred to the accelerator table through the back side of the CT gantry's central opening 59, and through the wall opening 5, directly as described under FIG. 13, without any need for the accelerator table's rotation.

Permanently or semi-permanently, this special purpose accelerator 61, can be equipped with the necessary field shaping collimator 62, for special procedures such as the stereotactic radiosurgery or intraoperative radiosurgery at those Radiation Oncology centers where these procedures are frequently done. Of course both these accelerators 1, and 62, can be fitted with

the special field shaping collimators and can be used for the special procedures . The advantage of equipping one accelerator in the configuration as with the accelerator 61 with the CT in this FIG. 14, is that it can take the full advantage of the CT combined accelerator to improve the quality and the cost efficiency of such treatments. It improves the patient setup and field verification, eliminates the waiting time for access to an accelerator and the dead time for CT data transfer from the Radiology department to the Radiation Oncology department for treatment planning. At a Radiation Oncology Department where many stereotactic radiosurgeries are done, the weekly number of such procedures is limited to about four patients. It is because of the a waiting for access to an accelerator, delay in CT data transfer from the Radiology department to the Radiation Oncology department for treatment planning and the subsequent efforts to set up the patient on the accelerator table identically as the CT images was obtained at the Radiology department's CT. Excluding the waiting time for the access to the accelerator, the present turn-around time for the stereotactic radiosurgery is about four hours. The technical improvements of this invention not only reduces this turn-around time from four patients a week to very many more, but also improves the quality of this treatment significantly. The improvement of the quality of this treatment is much more important than the cost savings. This invention significantly improves both the quality and the cost efficiency of these specialized radiation therapy and therefore makes them available to a large number of patients everywhere. The special field shaping collimator can also be fitted on to the accelerator setup as in FIG. 12 but at a sacrifice of accelerator time for the frequent change of the field shaping collimator and the need to wait for access to the accelerator until the daily regular patient's treatment have been completed.

The patient transport to the accelerator table and bringing the patient under the accelerator's treatment head from the CT facing directly to the accelerator 1, and the CT placed at 90 degree to the accelerator 1, is with a 180 degree rotation in the former instance and with a 90 degree rotation in the latter case. It is further described under FIG. 10 and 12.The rest of the identifying numerals in this FIG.14 are as the same as in FIG. 1.

In FIG. 15, a different configuration of a single accelerator room with four CT 7, connected to it is shown. In this configuration, the accelerator 1, is centrally located and the four CTs 7, surrounds it. As in Fig. 1, the wall openings 5, are opened and closed with sliding shield doors 9. The general operational features for the patient transport from the accelerator room to the CT rooms through the wall openings and bringing the patient under the accelerator's treatment head are as described in the former detailed descriptions of this invention. The main purpose of this illustration is to demonstrate that several CTs can be added to this CT combined with the

accelerator for the cost efficient and improved quality radiation therapy of cancer and for the routine diagnostic imaging. The identifying numerals, 1-12, in this FIG. 15 are as in FIG. 1.

FIG. 16 illustrates the motor driven and the manual opening and closing of the sliding shield doors made of radiation protective metals and screws and its support mechanism. Provision is given for attachment of multiple slabs of heavy metal sheets 9c, to make the weight of this mobile door to be distributed among the multiple individual metal sheets at the accelerator side's wall opening. At the side of the imaging room a single slab metallic sliding shield door 9d, (FIG. 26) is attached as this is sufficient for the radiation protection from the diagnostic x-ray machine's kVp range of photon's energy and from the scattered radiation from the sliding shield door at the side of the accelerator room. The required thickness of the metallic sliding shield door is calculated based upon the common formulas integrating the workload (W), use factor (U), occupancy factor (T) and the distance (d). The wall opening for the transport of the patient from the CT room to the accelerator room is placed in the secondary barrier wall (Khan, F. M., Radiation protection; in The Physics of Radiation Therapy, 2nd ed., 474- 503, 1994; Shleien, B., Exposure and shielding from external radiation; in The radiation Physics and Radiological Health Handbook, 163-218, 1992).

The cross sectional view in FIG. 16, illustrates the sliding shield door as mounted on to the concrete wall. The metal channels 63 in the lower section of the concrete wall 65, and similar metal channels 64, in the upper section of the concrete wall 65, serves as the guide for the sliding door 9. It is fitted with a mechanical handle 66, to move to the opened and closed positions of the wall opening 5. The lower section of the sliding shield door is fitted with metal fasteners 67. It is further illustrated in FIG. 18. This door is compartmentalized as a series of slabs of doors which can be adjusted according to the required amount of shielding material needed for a particular sliding shield door. Also the weight of the shielding material is shared by these slabs than if this mobile door is made of a single compartment. The sliding shield door is driven to the open and closed positions by a motor driven mechanism when the weight of the sliding shield doors exceeds the limit that can be easily pulled and pushed by hand. Alternate to the sliding shield door, a conventional medical accelerator's beam shield can be adapted as sliding from one end of the wall opening to the other for the opening and closing of the wall opening with adequate shielding. It is like the sliding shield door.

In FIG. 17, the cross section of the top of the sliding shield door is shown. It comprises of the metal fasteners 68, with its guide 69, for its rollers 70, to slide through the metal channel 64. The shielding material 71, is screwed into the metal fastener 68. This top section of the sliding shield door is shown as attached to the upper portion of the concrete wall 65.

FIG. 18 illustrates the cross section of the bottom portion of the sliding shield door. Its metal fasteners 67, are fitted with vertically installed wheels 72, for the sliding shield door's travel through the metal channel 63. The shielding material is screwed into the lower metal fasteners 67. This lower section of the sliding shield door is fitted on to the lower portion of the concrete wall 65.

In FIG. 19, an alternate method of constructing the sliding shield door is shown. In this case the shielding material is in the liquid form which runs to the hollow core of the sliding shield door 73, which is installed with a set of inlet 74, and outlet 75, hoses. The core of this sliding door is divided into multiple cells. The number of cells filled with the liquid shielding material is based up on the required shielding for a given energy radiation and the position of the wall opening in relation to the accelerator. Whenever the wall opening 5,needs to be closed, the sliding hollow core door is pulled towards the wall opening and the hollow core door is kept in its locked position and filled with the liquid shielding material. The liquid shielding material is allowed to run from a reservoir 76, in the concrete wall at the top of the wall opening by opening the valve 82, (FIG. 20 and 21) and through the hose 74 into the multi cells of the sliding hollow core door. The valve 84, inside the hollow core door controls the fillings of the individual cells 86, 87, 88, (FIG. 20,21). Simultaneously, the multi-cell's outlet valve 91, (FIG. 22) is closed to prevent the flow of the liquid shielding material through the outlet hose 75, at the bottom of the sliding hollow core door. The core of this hollow door is allowed to fill with the liquid shielding material 93, (FIG.21). After filling the hollow core door with the liquid shielding material the flow valve 84, is brought into the closed position as in FIG. 20 and 21. Simultaneously, the outlet valve 82, of the upper reserve tank is also brought to its closed position (20,21 23) When the wall opening 5, is to be opened, the drain valve 91, (FIG. 22), at the bottom of the sliding hollow core door is released and the liquid shielding material is allowed to flow through the outlet hose 75, to a drain tank 78, located below the wall opening 5, in the concrete wall. The sliding hollow shield door is then moved away to the side of the concrete wall to open the wall opening 5. The sliding hollow core door rests upon its side on a metal channel 79. It is fitted with rollers 92, and guide 80, (FIG. 21) to slide this door to open or close the wall opening 5. The clamps 83, is used to attach the loose mid portions of the hoses 74 and 75 to the top and the bottom of the sliding door so that it will not interfere with the movements of the sliding door. Two succession pumps in the concrete wall 77, one at the bottom and the other at the top of the wall opening 5 are connected to each other with a pipe line 81. The liquid shielding material is pumped from the draining tank 78, to the top reservoir 76, for the refilling of the sliding hollow core door for the next time when it is brought in position as a shield door in front of the wall opening 5. Adequate lead sheets are

placed in front of the concrete where the fittings of the sliding shield door's accessory equipment have created defects in the required wall thickness.

FIG. 20 shows the cross section of the top of the sliding door with the inlet valve 82, which controls the individual cell's 86,87,88, filling with the liquid shielding material which flows through the hose 74, to the hollow core of the sliding door. The inlet valve 84 is moved from one cell to the other for each cell's filling. In the three consecutive illustrations in FIG. 20 the first slight movement of valve 84 to the right allows the flow of the liquid shielding material to the first cell 86, through the first valve opening 85. In the illustration in the middle, the valve 84 is moved further to the right to open the inlets 89,of the both first and the second cells 86, 87, to allow the flow of the liquid shielding material into both these cells. In the right last illustration in FIG. 20, the valve 84 is moved further to the right to open the inlet 90,of all three cells 86, 87, 89, to fill all of them with the liquid shielding material. By consecutive movement of the valve 84 towards the left, the inlets of the third, second and the first cells 88, 87, 86, are closed. Thus the cells are filled as one by one to meet the required thickness shielding material in the sliding door. It gives the flexibility to use the same multi-cell sliding hollow core door at various sites with the site specific required thickness shielding material. An alternative to the multi-cell hollow core door is the multiple single cell hollow core door which are connected individually to the reserve tank 76, and to the drain tank 78 and is attached to individual metal channel 79, guide 80, and the rollers 92. This arrangement gives the flexibility to distribute the weight of the liquid shielding material to multiple individual sliding hollow core doors. It is illustrated in FIG. 23. Sensor switches attached to the lateral sides of the hollow core door automatically stops the movement of the sliding door if it encounters any obstruction in its path. Interlocks connected between the sliding hollow core door and the accelerator assures the radiation beam on only if the required cells are filled with the liquid shielding material and the wall opening 5, is completely closed. When multiple diagnostic devices are combined to an accelerator, there will be multiple wall openings 5, as described before. If any of the wall opening is in open position, incompletely closed or the sliding hollow shield door is incompletely filled with the liquid shielding material, the interlocks to the accelerator will make the accelerator not to activate to produce radiation. The commercial accelerators are integrated with interlocks to check the status of the door opening. This interlock is connected to the interlocks of the sliding shield doors and the wall openings.

In FIG. 21, the top section details with the inlet valve 84, in its closed position after filling the sliding hollow core door's 73, cells 86,87,88, with the liquid shielding material 93, and the closed position of the inlet valve 82, at the level of the inlet hose 74, is shown. The metallic

channel 79, is screwed on to the concrete wall 65. The guide 80, and the roller 92, for the sliding movements of the door on the metallic channel are also illustrated.

FIG. 22 illustrates the sectional details of the bottom of the sliding shield door. The outlet valve 91 is brought to its closed position to prevent the flow of the liquid shielding material from the multi-cell compartments of the core 73, of the door to the outlet hose 75. The metallic channel 79, is screwed on to the concrete wall 65, at the bottom of the wall opening, The guide 80, and the rollers 92, aids in the sliding of the door on the metallic channel 79. The first second and the third cells 86, 87, 88, in the core of the door are filled with the liquid shielding material 93. When the sliding bottom outlet valve 91, is slid to the right, the valve is brought in open position and the shielding liquid material flows from the cells to the drainage tank 78, (FIG. 19) through the outlet hose 75. The valve is brought to the left to stop the drainage of the liquid from the cells by closing the outlets.

FIG. 23 demonstrates the sectional view of a single cell sliding shield door's top inlet and its sliding mechanism. Except for the single cell arrangement of the sliding shield door's core 73, the rest of the door, its inlet and outlet valve's operation and its sliding mechanism are identical to the top sectional view of the multi-cell sliding hollow shield door as illustrated in FIG. 21. In this case, only one cell needs to be filled by the inlet valve 94, with the liquid shielding material. Multiple single cell hollow core door are connected individually to the reserve tank 76. It is attached to individual metal channel 79, with guide 80, and the rollers 92. The single cell's drainage mechanism is similar to the multi-cell door's drainage system but with minor modifications. It is shown in FIG. 24. Each of the cells outlet hose 75, is connected to the drain tank 78.

FIG. 24 shows the sectional view of a single cell sliding shield door's bottom outlet and its sliding mechanism. Except for the single cell arrangement of the sliding shield door's core 73, the rest of the door, its outlet valve's operation and its sliding mechanism are identical to the bottom sectional view of the multi-cell sliding hollow shield door as illustrated in FIG. 22. In this case, only one cell needs to be emptied from the liquid shielding material by the outlet valve 91. Multiple single cell hollow core door are connected individually to the draining tank 78, by each door's drainage hose 75. As in FIG. 22, each single door's bottom section is attached to individual metal channel 79, for sliding of the door with guide 80, and the rollers 92.The single cell arrangement gives the flexibility to distribute the weight of the liquid shielding material to multiple individual sliding hollow core doors. Each of these doors are brought in front of the wall opening 5, for its closure and moved away for its opening.

FIG. 25 demonstrates a different wall opening and closing mechanism than the previous ones. In this case, a rotating cylindrical solid shielding door 95, with a central opening 96, is inserted at the site of the wall opening 5. This cylindrical shield made of steel hollow core and filled with lead is made to rotate with the aid of motor driven chain mechanisms 97, which are attached to the top and bottom of this cylinder. This drive mechanism is inserted to the concrete wall which at the site of the wall opening 5, is modified 98, for the accommodation of the cylindrical shield. The deficient thickness created in the concrete wall by attaching this drive mechanism is compensated with lead sheets. Also provision is made for the mechanical rotation of the cylinder with a retractable handle 99, in case of emergency. By rotating the cylinder, the wall opening is brought to open position 100, as illustrated in the upper drawings or to closed position 101, as illustrated in the bottom drawings in FIG. 25. Like before, the safety of this cylindrical shield's operation during the opening and closing of the wall is assured by safety interlocks. The accelerator's interlock for the door is connected to this cylindrical door. The accelerator will be activated only if the wall opening is closed completely and the cylindrical door is at a predetermined position to assure the required full thickness shielding of the wall opening.

FIG. 26 is a view of the sliding shield door from the accelerator side of the wall opening and from the side of the diagnostic room. The wall opening 5, is shown as opened. At the accelerator side, the configuration the sliding shield doors are as described in FIG. 16. Multiple slabs of shielding materials 9c,are shown. At the diagnostic imaging side of the wall opening, its opening and closing mechanism is as at the accelerator side except for the single slab sliding shield door 9d.

FIG. 27 is a view of the accelerator side's sliding hollow core door with the filling and draining of the liquid shielding material as was described in FIG. 19. The opposite, the diagnostic imaging device's side of the wall opening 5, is fitted with a single slab sliding shield door 9d, as in FIG. 26.

FIG. 28. illustrates a different configuration of the accelerator room with mazes to reduce the shielding at the wall opening. In this instance, the secondary barrier wall 102 in front of the accelerator table is interposed in between a shorter maze wall 103, and a longer maze wall 104. The longer maze wall 104, with the opening 105, for the door 106, and the shorter maze wall 103 circumvents the maze wall 102. The maze wall 102, has an opening 107, with a door 108. This opening 108, is at 0 degree to the accelerator table. The double doors 108, and 105, facing this opening 107, and the distance from the accelerator to the ante-room's 109, wall 110, assures only much decreased energy scattered radiation reaching these openings in the shared walls of the diagnostic room and the accelerator's ante-room. The openings in the concrete wall for patient

transport from the diagnostic table are placed away from the direct path of radiation from the accelerator. By this arrangement, only multiply scattered radiation with much reduced energy will reach the wall openings 111. In general, the construction of an accelerator room is done with maze walls to reduce the shielding requirement for door. With maze walls, the shielding for the door of a medical accelerator room is reduced to about less than 6 mm of lead for most facilities. The same principle of multiply scattered radiation with much reduced energy reaching the wall openings 111, for the connection of the accelerator room with the diagnostic room is applied here. Because of this reduced shielding requirement, the doors 112, at these wall openings 111, are treated like in the design of door for a medical accelerator. Such construction will also allow to make reduced thickness sliding shield door as was previously described in FIG. 16 and 19.however, the patient transport through a door opening is far more convenient than through the smaller wall opening 5. From the diagnostic table 8, the patient is transferred to a modified extension table 113, with rollers and is rolled on the tracks 114, leading to the accelerator. The back side of the diagnostic device's gantry's opening 59, faces the ante-room's wall opening 111, and its door 112. This allows the routine imaging of a patient with a device like the CT and the subsequent patient transport to the accelerator room. For imaging of the head and neck region, a head holder 51, (FIG. 9, 10) is attached to the present CT. Through the backward exit 59, of the gantry of the diagnostic device, (FIG. 12) the patient is transported to the extension table and then to the accelerator table. The top section of this extension table 113 can be rotated to 360 degree to allow the patient's transport from any of the wall opening conveniently. This allows the patient to be placed on accelerator table with the head closer to the accelerator's gantry, the common treatment position of a patient on the accelerator table. Through the guide rails 113, the extension table with the patient is brought to the accelerator room. The accelerator 1, with its table 2, as retracted towards its gantry 57, to make room for attachment of the extension table is shown in the accelerator room 3. The flat table top insert 17, (FIG. 3) with the patient is rolled over to the accelerator table by rolling its rollers 24, on the grooves 31, of the accelerator table(FIG. 9.10.13). Only one patient at a time is brought to the accelerator's ante-room space 109. When the accelerator is idle, a patient whose setup and verification is completed is brought to the accelerator through the ante-room space 109. The extension table is connected to the accelerator table as described in FIG.7 before the patient's transfer to the accelerator table. The diagnostic rooms 6, with the table 8, and the gantry 18, are oriented towards the accelerator room at an angle to facilitate the transport of the extension table on the tracks attached on the floor at relatively straight paths. The diagnostic device's control room 115, and the utility room 116 are also shown in this figure.

In addition room 117,for special procedures such as surgery 118, is attached to the ante-room of the accelerator room through the door 119. Its door 120 opens to a diagnostic room and its door 121, is for entry and exit from outside. This unique arrangement would greatly enhance both the quality and cost efficiency of the surgery combined 3-D conformal radiation therapy. The needed special surgical procedures can be done within the close proximity of a diagnostic device such as a CT or an MRI. At present, often surgery is done at a room far away from the diagnostic CT or MRI with the attempted correlation with the images previously obtained and subsequent transport of the patient to an accelerator from this distant operating room for the intraoperative 3-D conformal radiation therapy. The advantages associated with the availability of a surgical suit in association with a CT or MRI unit and the accelerator for improved quality and cost efficiency is obvious. It also facilitates the delivery of the brachytherapy combined surgery and 3-D external radiation therapy with greater precision due to the same advantages as the precise and online target treatment volume definition at surgery in a surgical suit in close proximity of an accelerator combined with a diagnostic device.

FIG. 29. Is an other illustration of a different configuration of the accelerator room with mazes to reduce the shielding at the wall openings 105, for entry to the accelerator room from the ante room space 109, and the wall openings 111, at the shared wall of the diagnostic room and the ante-room. In this instance, the opening 107, in the secondary barrier 102, is eliminated. This further reduces the energy of the scattered radiation reaching the door 106 and the ante-room space's doors 112. It reduces the required shielding for these doors. It also allows to construct the ante-room 109 with shielding equivalent to a x-ray room when the diagnostic device used in the adjacent diagnostic room is an x-ray generating unit such as a CT. The patient is transported from the diagnostic table 8, to the ante-room 109, through the door opening 112. From the diagnostic table 8, the patient is transferred to the modified extension table 113; as in FIG. 28 and is rolled on tracks 114 to the accelerator room. This tracks 114, begins at the diagnostic room and passes through the wall opening 111, to the ante-room 109, and enters the accelerator room with bending 122, to circumvent the barrier made by the maze wall 102. Except for these modifications, the structural and functional features as well as the identifying numerals shown in FIG. 29 are identical to those in FIG. 28.

FIG. In FIG. 30, a modified version of the single accelerator 1, combined with multiple diagnostic devices 7is shown. In this case, the configuration in FIG. 15 is modified with maze walls that surrounds the accelerator. The secondary barrier 123, in front of the accelerator table has an opening 124, for entrance and exit to the accelerator room 3, through this accelerator's ante-room 125. To reduce the weight of the door 126, at the opening 124, in front of the

accelerator table, it is made with lesser than the required shielding material but the radiation that leaks through this door is absorbed by the ante-room's walls. The two side wall doors 127, to the ante-room 125, allows entrance and exit to the ante-room. At these doors only multiply scattered low energy radiation will reach and hence only much reduced shielding is required. A semi circle curved track 128, on the floor surrounds the accelerator room. It connects with each of the diagnostic rooms 6, that surrounds the accelerator and passes through the ante-room 125. The diagnostic rooms 6, are arranged at a hexagonal angle to the accelerator room. The track 128, runs through the floor in between the accelerator room and the diagnostic room. It is also connected to the accelerator room as it enters the accelerator room's floor through the secondary barrier's 123, opening 124. A perpendicular track on the floor 129, runs from the ante-room to the accelerator room and ends in front of the accelerator table 2. It thus connects the semi-circular track 125, with the accelerator room. The extension table 113, is used to transport patients from the diagnostic tables 8, to the accelerator table 2. The diagnostic room's back exit door 130, opens to the secondary space 131, in between the diagnostic room and the accelerator room in the hexagonal arrangement of the diagnostic room around the accelerator. The initial patient setup and verification is done with the diagnostic device and subsequently, the diagnostic table 8, is extended to the secondary space 131, through the accelerator gantry's back exit 59, and the diagnostic room's back exit door 130. The extension table is rolled on the semi-circular rails 128, on floor to bring it near to the diagnostic room's back exit door 130. The extension table's rotating table top section is rotated to the diagnostic table and both tables are connected together and the patient is transferred to the extension table. After disconnecting the tables, the extension table's top section is rotated to bring it back in parallel to the rails on the floor 128, and the extension table is rolled to the ante-room and then to the accelerator room on connecting rails 129. The patient is transferred to the accelerator table 2, by rolling the flat table top insert with the patient on the grooves 31, of the accelerator table's cradle (FIG.11). In principle, the patient's transfer from the diagnostic table to the accelerator table is the same as described under FIG. 7, 9, 10, 13, 28 and 29, but with the necessary adaptation for a given configuration of the room's layout. The entry and exit to the secondary room 131, in between the accelerator and its ante-room and the diagnostic room is through the two doors 132, at both ends of the hexagonal layout of this configuration. The diagnostic rooms are equipped with entrance and exit doors 10. The accelerator room's greater thickness concrete wall 11, and the diagnostic rooms lesser thickness wall 12, are also shown in this illustrations.

FIG. 31 shows two accelerators with multiple diagnostic devices. The accelerator 1, is equipped with a special purpose collimator 62, for special procedures such as the radiosurgery

and is configured at one end of the ante-room 109, and closer to the surgical room 117. The other megavoltage radiation therapy machine 123 is placed at the other end of the ante-room 109, and is a conventional accelerator for conventional megavoltage radiation therapy. The rest of the illustration identifying the parts of the diagnostic imaging device, the surgical room, the tracks, the extension table, the wall and door openings, and the maze wall arrangements are as described in FIG. 28.

From the above descriptions, the following elements of this invention is obvious:

After the desired patient setup is done with the CT, the CT-table with the patient is moved towards an opening in the shared wall of the accelerator and the CT room. The accelerator table is also moved towards this common opening in the wall and the both tables are latched together. The patient is then brought to the accelerator table by moving the CT cradle towards the accelerator table. The patient is then transferred to the accelerator table without any changes in the patient's setup. Once the patient is moved to the accelerator table, the CT-cradle is retracted and the wall opening is closed with a protective shield for radiation protection. The CT-table is then aligned with the accelerator's treatment head and the radiation treatment is given to the desired anatomic region of the patient. After the treatment is completed, the patient leaves the accelerator room through its exit door and the next patient whose setup is completed in the next adjacent CT room is brought into the accelerator room and treated.

The disadvantage of the openings in the secondary barrier wall is that it will need doors with heavy shielding material. The required secondary barrier for the leakage radiation far exceeds the required secondary barrier for the scattered radiation in the megavoltage range. Unless a maze wall arrangement is made to prevent the direct incidence of radiation at the shield door, this door may weigh about 750 kg for a 6 MV accelerator beam. This heavy weight of the door is an inconvenience. In this case, the weight of the shielding door is distributed to multiple sliding doors. These sliding shield door is like the beam shield attached to an accelerator. Provision for manual operation of these doors are also made. The arrangement without the maze walls has the advantage of easier patient transportation than the arrangement with the maze walls in between the secondary barrier.

With the maze walled accelerator room, the door openings are exposed only to the multiply scattered radiation of much reduced energy. Like the door shielding of an accelerator room, with maze walls interposed between the secondary barrier walls, the required shielding at the door openings for a usual accelerator room is reduced to about 6 mm thick lead. This allows to make larger wall opening with reduced shielding for the door and the patient transport through the door is easier. To take advantage of the reduced shielding requirement at the door openings when

maze walled accelerator room construction is elected, this invention also includes construction of the accelerator room with maze walls. It also includes an ante-room to the accelerator room with required shielding. In this instance, the patient is first transferred from the diagnostic room to an ante-room to the accelerator through the shared doors between the diagnostic room and the ante-room and then to the accelerator room on extension table on rails. Which of these system is elected is based upon the specific needs and the economical and the structural considerations of a specific treatment facility.

After checking for the satisfactory positioning of the patient on the accelerator table, the technical personal leaves the room and the doors are closed. The shield door's interlock with the accelerator console assures the double check for the proper closure of the shield doors. If any of the doors are opened or improperly closed, the accelerator will not operate. The accelerator room and the patient are monitored by close circuit TVs. Communication with the patient is maintained by microphone and speakers at the control console when the doors are closed. These precautions are routine practice in radiation therapy of patients and the commercial accelerators are equipped with such interlocks.

This configuration of multiple CT with one accelerator allows the rapid turnover of patients in the accelerator room. The time taken to deliver the usual about 200 cGy for daily treatment by the accelerator is only about less than a minute. The total time taken for the transport of the patient from the diagnostic table to the accelerator table, closure of the wall opening and the automatic accelerator's treatment setup as per each patient's initial plan and completion of radiation takes much lesser time than when the patient setup and treatment is done with the accelerator alone. For conventional radiation therapy, the former may take about less than 5 minutes while the latter may take at least about 20 to 25 minutes on the average. If the verification port films are also to be taken with the accelerator, the time taken by the accelerator to complete a patient's setup and treatment can almost double than the routine daily treatment. 3D conformal radiation therapy like the radiosurgery for intra-cranial lesion the average time taken is much longer. Therefore at present only about four patients are treated by stereotactic radiosurgery for intra-cranial lesions per week. Because of the reduced time taken for a patient's treatment at the accelerator, about for to five time more patients can be treated with a single accelerator. It enhances the cost-efficiency of this system. At present, the diagnostic device like a CT scan is much more cheaper than the accelerator and hence addition of multiple diagnostic devices like the CT scans would not increase the overall cost of this system.

In this invention, the daily patient setup is verified by the CT with much superior anatomical delineation of the tumor site and its surrounding normal tissue before each day's treatment. The

present existing methods of radiation therapy with accelerator do not have this capability. The changes in the body contour due to loss of weight swellings or other reasons, the changes in the tumor volume under treatment and its changing anatomical relation to its surrounding normal structures and the accurate estimation of the geometric outline of tissue inhomogeneities of the treatment regions are all estimated with the daily setup CT image. This CT image is used for the daily on-line CT integrated dosimetric calculations with a treatment planning computer. It is displayed on a TV monitor as superimposed on the daily setup CT image. Commercially available treatment planning computer is integrated with the CT combined accelerator system, for the daily treatment verification. For the daily treatment setup and verification, only orientation one or two CT slice may be needed and hence patients are not kept long on the CT table. This greatly improves the overall quality of the daily dosimetric calculations and the quality of daily treatment. It also adds to the ease with which the daily treatment setup is done and the treatment port with superimposed dosimetry is verified. Such on-line quality control checkup before each day's treatment is presently not available and is not feasible.

The CT combined accelerator as in this invention, also improves the quality and the cost efficiency of conformal radiation therapy. It improves the patient setup and field verification, eliminates the waiting time for access to an accelerator and the dead time for CT data transfer from the Radiology department to the Radiation Oncology department for treatment planning. The technical improvements of this invention facilitates the stereotactic radiation therapy of many patients a day than the present four patients a week. It also improves the quality of this treatment significantly. The improvement of the quality of this treatment is much more important than the cost savings; but through the significant cost savings of this invention, very many patients can benefit from this advanced form of radiation therapy.

In brief, this invention's capabilities allows the improved quality and highly cost effective radiation therapy for cancer as the following. The patient is brought to the CT room and is placed on the CT table in the desired treatment position. When needed, the patient position is further secured with patient immobilization devices. Port verification limited CT are taken for comparison with the initial setup and the treatment plan. With the aid of a treatment planning computer, the initial setup treatment plan is superimposed on this CT for comparison. This enables the daily on-line verification of the setup and dose distribution of the intended treatment. After making the necessary adjustments in the setup if necessary, the motor driven CT table with the patient on it is advanced towards the opening in the wall or to the accelerator's ante-room. When the patient is transported through the wall opening, the accelerator table from the adjacent accelerator room is also brought to the opening in the wall. The tables are connected and fastened

together. Through the track on the table tops, the patient is moved from one table top to the other and thus brought from the CT room to the accelerator room. After closing the wall opening with the sliding shield door, the CT room and the accelerator rooms are separated and functions independently of each other. The patient on the accelerator table is placed under the accelerator's treatment head and the treatment to the desired anatomical site as was setup and verified with the CT is given. In the alternative arrangement with an ante-room to the accelerator, after the patient setup and verification in the CT room is completed, the patient is transferred from the CT table to an intermediate accelerator table and which is then rolled on tracks attached on the floor of the ante-room and leads to the accelerator room. The patient is then transferred to the accelerator table. After completion of the treatment, patient leaves the accelerator room through its door. In the CT room, a new patient setup will begin. The time taken to complete the radiation with the accelerator is much shorter than the patient setup and verification with the CT. This difference in time taken for setup and verification by the CT and the actual treatment by the accelerator allows treatment of several patients with one accelerator within the time period of a single patient setup and verification by the CT. This allows to bring in an another patient to the accelerator room whose setup and verification has completed with an other adjacent CT. This follows an other patients radiation treatment whose setup and verification is completed in an other CT room. Whenever the accelerator room and the CT rooms function independently, all the connecting wall openings and doors are closed. In this manner, a single accelerator can treat very many patients with much higher accuracy than when the patient setup, verification and the treatment all are done with the accelerator. It also reduces the turn-around time for 3D conformal radiation therapy and stereotactic radiosurgery while improving the quality of this treatments further as described earlier. When the diagnostic device is not in use with the accelerator, it is used as a stand alone imaging device of a diagnostic Radiology Department. All these combined advantages of this invention provides a great deal of cost savings in the radiation therapy of cancer while the quality of this cancer treatment is many fold improved.

BEST MODE CONTEMPLATED

The shielding requirement at the secondary wall opening in FIG.1 will be much higher than for the alternative arrangements of the megavoltage radiation therapy machine and the diagnostic imaging devices as with an ante-room to the accelerator through which the patient is transported. There are a number of ways by which the ante-room to the megavoltage therapy room can be constructed. These various modes arrangements are shown in FIG. 28, 29, 30 and 31. With the maze walls and the ante-room, the shielding requirement at the wall openings are much reduced

and the patient is transported through a door opening instead of the wall opening in the middle of the secondary wall as in FIG. 1.

SUMMARY OF THE INVENTION

The present invention is a combined cost effective system for diagnostic imaging and radiation therapy. The cost effectiveness of radiation therapy component is achieved by means of reducing the idle time of the accelerator during the usual working hours of the day. It also increases the cost efficiency of the conformal radiation therapy. The cost effectiveness of the imaging component is achieved by its combined use as a diagnostic imaging devise in a Department of Radiology and as an accessory devise for patient setup and the on line verification of the intended treatment in a Department of Radiation Oncology.

In this invention any of the commonly used diagnostic imaging devices is used for the initial patient setup and verification. Such imaging devices include but not limited to CT, MRI, US, tomographic X-ray, the nuclear medicine imaging devices such as the SPECT and PET scans..

To achieve this purpose, the invention is provided with an accelerator in the accelerator room which is connected to multiple CT in the adjacent CT rooms. The accelerator room is connected to the CT rooms either by openings in the common wall of the diagnostic rooms and the accelerator room or by means of an ante-room to the accelerator room to which the CT room's doors opens. A patient at a desired treatment position on the diagnostic table in the CT room is moved to the accelerator table in the accelerator room or visa versa through the wall opening or through the ante- room of the accelerator. After the patient's transfer to the desired room, the wall opening or the door to the ante-room is shut with a radiation protective door of desired material and thickness. With the door closed, both rooms function independently of each other. The patient is treated in the accelerator room while the next patient's setup and its on line verification proceeds in the CT room. After completion of radiation therapy in the accelerator room, the patient leaves the accelerator room through its common entry and exit door. The patient for desired treatment setup enters the diagnostic room through its common entry and exit door. After the patient's setup is verified in the diagnostic room, the door is opened for the patient's transport to the accelerator room. The patient setup and the desired treatment verification is much more time consuming than the actual delivery of the radiation by the accelerator in the accelerator room. Since multiple CT are connected to the accelerator room, a patient whose setup and treatment verification is completed in any of the multiple CT room is transferred to the accelerator room while other patient's setup and verifications are in progress in other CT rooms. This configuration of accelerator and the CT allows more patients to be treated

with a single accelerator. When the CT is not in this combined use with the accelerator for radiation therapy of cancer patients of the Radiation Oncology Department, it is used for the routine diagnostic studies of patients of the Diagnostic Radiology Department.

Another object of this invention is the provision of a patient transport mechanism from the CT room to the accelerator room without changes in the verified patient's treatment setup position by the diagnostic devise. It is being done by aligning and latching together the diagnostic table with an extension table or the accelerator table and transferring the flat table top insert with the patient from one table to the other by rolling it to the accelerator table.

A further object of this invention is the provision of both manually controlled and motor driven radiation protective shutter for opening and closing of the wall opening. With the shutter closed, the accelerator and the diagnostic device can function independently of each other. With an open shutter, the patients is transferred from one room to the other. The facility safety interlocks of the accelerator and the diagnostic device's control console is connected to the shutter to assure safety from the scattered radiation. If the shutter is not fully closed, a warning red light will come up and the machines will not operate to produce radiation.

A still further object of this invention is the provision of maze wall arranged accelerator room to reduce the radiation energy that reaches the wall openings for the connection with the diagnostic device. In this instance the shielding requirement for these openings is treated like that for the accelerator door where multiply scattered radiation with much reduced energy is encountered. With maze walls, the accelerator room is configured with an ante-room in front of it. Patients are transported from the CT room to the accelerator's ante-room space first and then to the accelerator table by means of connecting tables.

A still further object of this invention is the increased accelerator usage by separating the more time consuming patient setup for treatment and treatment portal verifications from the accelerator.

A further object of this invention is the daily on-line pre-treatment verification of the previously planned treatment by daily single or multiple slice check CT with superimposed isodose treatment plan for conventional radiation therapy and for 3DCRT.

Another object of this invention is the provision of an alternate configuration with multiple accelerators combined to the CT to allow both the routine radiation therapy and special purpose radiation therapy such as the stereotactic radiosurgery.

One other object of this invention is the provision of CT-simulation of a patient for radiation therapy with a diagnostic imaging CT that is connected to the accelerator in a manner as to allow

the patient transport from the CT table to the accelerator table without any changes in the patient setup done by the CT.

Another major object of this invention is the use of the CT in combination with the accelerator for radiation therapy by the Radiation Oncology Department and as the diagnostic device for diagnostic imaging by the Diagnostic Radiology Department.

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CLAIMS

The disclosure of the invention described herein above represents the preferred embodiments of the invention; however, variation thereof, in the form, construction and arrangement of the accelerator and the CT thereof and modified application of the invention are possible without
1040 departing from the sprit and scope of the appended claims.

What is claimed is:

1. A system comprising of means for megavoltage radiation therapy and means for diagnostic imaging for conventional radiation therapy, on-line port verification, 3D conformal radiation therapy, radiosurgery, or intraoperative radiation therapy and diagnostic imaging in
1045 which the means for megavoltage radiation therapy, diagnostic imaging and surgery are configured in the adjacent rooms and the they are joined together by means of connection through which patients from the diagnostic room can be transported to the megavoltage radiation therapy room for radiation therapy wherein the patient setup for radiation therapy, treatment simulation and on-line port verification is done by means for diagnostic imaging and means for
1050 treatment planning computations and thereby freeing the means for megavoltage radiation therapy from the time consuming process of patient setup and port verification to allow delivery of improved quality radiation therapy to a great number of patients everywhere at much lesser cost by cost efficient utilization of the means of megavoltage therapy by significantly increased number of patients treated by a single means of megavoltage radiation therapy than its present
1055 utilization and when the means of diagnostic imaging is not in use with the means for megavoltage radiation therapy, it is used as means for the routine diagnostic imaging, said system comprising:

a means for megavoltage radiation therapy and means for patient transport and positioning for megavoltage therapy in a heavily shielded room (FIG. 1, 12, 15,
1060 and 28-31);

multiple means of diagnostic imaging with their modified tables located in the adjacent diagnostic rooms (FIG. 1, 12, 14, 15 and 28-31);

the said means of megavoltage radiation of the make of any of the following type as cobalt-60, Van de Graaff generator, betatron, microtron
1065 or the linear accelerator (FIG. 1, 12, 14, 15 and 28-31)

the said means of diagnostic imaging of the type CT, MRI, CT combined simulators or other diagnostic devices such as the ultrasonic tomograms or transverse tomographic x-rays (1, 12, 14, 15 and 28-31);

the said means of megavoltage radiation room and the said means of diagnostic imaging room are connected to each other by means of openings in their shared wall or through means of an ante-room to the said means of megavoltage radiation therapy (FIG. 1,12,14, 15 and 28-31);

the said wall openings being shielded with sliding opening and closing means with required thickness solid or liquid shielding material for radiation protection and the said ante-room doors being shielded by doors with means of required thickness radiation protective solid shielding material (FIG. 1, 2, 12, 14, 15, 16, 19, 26 and 27-31);

means for diminished shielding requirements to the maze-walled ante-room to the of megavoltage radiation therapy room and to its doors (FIG. 28-31);

the said ante-rooms are equipped with means for patient's transport(FIG. 28-31);

the said means for modified megavoltage radiation therapy table and diagnostic imaging tables fitted with means for patient's transport from the diagnostic table to the megavoltage therapy table in the same position of the patient as was used for treatment setup and verification on the diagnostic imaging table (FIG. 3-6, and 8-11);

an operating room with connections to the diagnostic imaging room and to the megavoltage radiation therapy room's ante-room with means for patient's transport from the surgical table to the megavoltage radiation therapy table for precise radiation therapy treatment setup and treatment verification by the means of diagnostic imaging and delivery of the prescribed dose to the tumor in the same position of the patient as was used for treatment setup and verification on the diagnostic imaging table for 3D conformal radiation therapy, radiosurgery, brachytherapy or intraoperative radiation therapy (28-29, and 31);

means of multiple said megavoltage radiation therapy machines for conventional radiation therapy and special procedure radiation therapy (FIG. 14, and 31)

2. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1,wherein the said system facilitates improved quality and low-cost conventional and advanced radiation therapy such as the 3D conformal radiation therapy, radiosurgery,

intraoperative radiation therapy and brachytherapy with 3D graphic display of the location of the implant to patients everywhere.

3. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein a centrally located megavoltage radiation therapy machine is connected to multiple diagnostic devices through the shared wall openings of the megavoltage radiation therapy room and the diagnostic imaging room (FIG.1).

4. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein an alternate structure with multiple maze walls and an ante-room to the said megavoltage radiation therapy room to minimize the energy of the scattered radiation reaching the door openings through which the patient from the said diagnostic imaging device's table is brought to the ante-room and to the accelerator room (FIG. 28-31).

5. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein the preferred radiation therapy machine being a medical linear accelerator or a medical microtron.

6. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein the preferred diagnostic device being CT, MRI or a simulator combined with the CT.

7. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein a flat table top insert with mylar, wood and tennis racket fitted on to its non-metallic frame and also with rollers fitted to its under surface for its travel from table to table as a vehicle for patient's transport and as the table top to the accelerator table for radiation therapy (FIG. 3 and 4)

8. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein the diagnostic device's table's cradle is fitted with two longitudinal non-metallic side grooves on which the rollers of the modified table top is rolled for its transport to the extension table (FIG. 3-6, and 8).

9. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein the extension table if fitted with longitudinal side grooves for the travel of the modified table top's rollers (FIG. 7, 28-31).

10. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein the cradle of the megavoltage radiation therapy machine's table is fitted with longitudinal side grooves on which the rollers of the modified flat table top insert is rolled as a means for its transport from the extension table to the megavoltage radiation therapy machine's table (FIG. 4, 8, 10, and 11)

11. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1,wherein the diagnostic imaging device's table's cradle, the extension table top and the megavoltage radiation therapy machine's cradle are latched and firmly connected together by means of latching clips and connecting male and female notches when the modified flat table top insert with the patient is transported from one table to the other (FIG. 7).

12. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1,wherin the patient transport from the diagnostic table in the diagnostic room to the accelerator room through the said common wall opening is accomplished by slow advancement of the flat table top with the patient on the rails of the tables and after the complete transfer of the flat table top insert with the patient to the megavoltage treatment table, its rotation to bring the patient's desired treatment site under the megavoltage treatment machine's treatment head in one instance or by transport of the patient through the door opening by rolling the flat table top insert with the patient from the diagnostic imaging device's table to an extension table as above and rolling the extension table on the rails fixed on the floor to bring the patient to the megavoltage treatment table and subsequent transfer of the patient to it and its rotation if needed to bring the patient's desired treatment site under the accelerator's treatment head (FIG. 9-10, 13 and 28-31).

13. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein the said megavoltage radiation therapy machine and the said diagnostic imaging devices are placed as the said megavoltage radiation therapy machine facing directly the back exit of the said diagnostic device and the other said diagnostic devices are placed at 90 and 270 degrees to the said megavoltage radiation therapy machine with the said diagnostic imaging device's front end and its table facing the said megavoltage radiation therapy machine to enable to bring the patient's desired treatment site under the said megavoltage treatment machine's treatment head without and with rotation of the accelerator table (FIG. 12).

14. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein the patients are transported from the said diagnostic imaging device's back exit and transferred to a said extension table and brought to the said ante-room to the megavoltage radiation therapy machine through the door and then transferred to the said megavoltage radiation therapy machine's table with the patient's head facing its gantry to minimize the need to rotate the tables to bring the patient's desired treatment site under the said megavoltage radiation therapy machine's treatment head since most treatments are delivered with the patient's head closer to the gantry (FIG. 14).

15. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein one said megavoltage radiation therapy machine is used for conventional daily radiation

therapy and the other said megavoltage radiation therapy machine is equipped with a special purpose collimator for 3D conformal radiation therapy or for radiosurgeries and it is placed behind a diagnostic imaging device that is sandwiched in between the two said megavoltage radiation therapy machines and its back exit facing the said special purpose megavoltage radiation therapy machine (FIG. 14 and 31).

16. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein a second special purpose said megavoltage radiation therapy machine with a special collimator for 3D conformal radiation therapy or for radiosurgeries is connected to it through the said megavoltage radiation therapy room's ante-room to which the patients from the surgical suit is brought on extension table that is rolled on rails either directly or through the adjacent said diagnostic imaging room (FIG. 31).

17. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein the said megavoltage radiation therapy machine is placed in a large hexagonal room and away from the primary beam's direction to take advantage of the distance traveled by the scattered radiation and thereby its reduced energy as it reaches the wall openings allowing to make reduced shielding material thickness sliding shield door for this wall opening through which the patient on the flat table top insert is transferred to an extension table as the patient is advanced through the back exit of the diagnostic imaging device and rolled to the megavoltage radiation therapy machine's table without any changes in the diagnostic imaging device's verified treatment position of the patient for treatment (FIG. 15).

18. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein the said megavoltage radiation therapy machine and the said diagnostic imaging machines are placed in a hexagonal arrangement with the said megavoltage radiation therapy machine enclosed in a heavily shielded room within this said hexagonal configuration and with a radiation protective ante-room to this said megavoltage radiation therapy room with rails connecting these rooms and to the said diagnostic imaging room for patient's transfer to an extension table which is brought in through its door which opens to a patient holding secondary room in between the said megavoltage radiation therapy room and the said diagnostic imaging rooms and the patient is transferred from the said diagnostic imaging device's table to an extension table and rolled to the said megavoltage radiation therapy machine's treatment table in the same position as the treatment setup was verified by the diagnostic imaging device for treatment (FIG. 31).

19. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein multiple slabs of sliding shield doors with required thickness solid radiation protective material are mounted on to the side of the connecting wall opening in between the megavoltage

radiation therapy room and the said diagnostic imaging room with motor driven and manually operating mechanisms as well as with metal channels, rollers and wheels for sliding the door to open and closed positions (FIG. 16 and FIG. 26).

20. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein the multi celled or single celled sliding shield door core attached to the concrete wall is intermittently filled and emptied in association with opening and closing of the wall opening with liquid heavy metal such as mercury or with metal alloys that can be maintained in the liquid form at slightly higher room temperature such as the Lipowitz metal and the liquid metal is allowed to flow through a hose from a reservoir placed on top of the wall opening and empties through a hose to a reservoir placed at the bottom of the wall opening, pumps, the connecting pipe between the reservoirs, the opening and the closing valves, the heating wires connected to all these components that are in operational association with this system and the metal channels and rollers for the sliding of the shielding core door (FIG. 19-24).

21. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein the shielding high density material include liquid metals such as mercury and Lipowitz metal at about 70 degree C and the conventional lead and concrete (FIG. 16, 19, and 26-27).

22. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein the concrete wall's opening for patient's transport from the said diagnostic room to the said megavoltage treatment room is shielded with an alternate rotating cylindrical shielding door with an opening in its center made of steel hollow core filled with lead and is made to rotate both by a motor driven chain and by mechanical handles to bring the wall opening in open or closed position (FIG. 25).

23. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein this system reduces the positioning errors as little as possible as the said diagnostic imaging device is used to image the treatment site in the precise treatment position and the patient is transferred from the said diagnostic imaging device's table to the megavoltage radiation therapy machine's table in the identical position as the treatment positioning as verified by the diagnostic imaging device.

24. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein on-line treatment portal with superimposed computer generated isodose to the true 3D visualized treatment region for conventional daily treatment and conformal 3D radiosurgery is done by the said diagnostic imaging device and associated treatment planning computer before the patient is transferred to the accelerator table and after such verification, the patient is brought to the accelerator table without any positional changes since the patient does not leave the

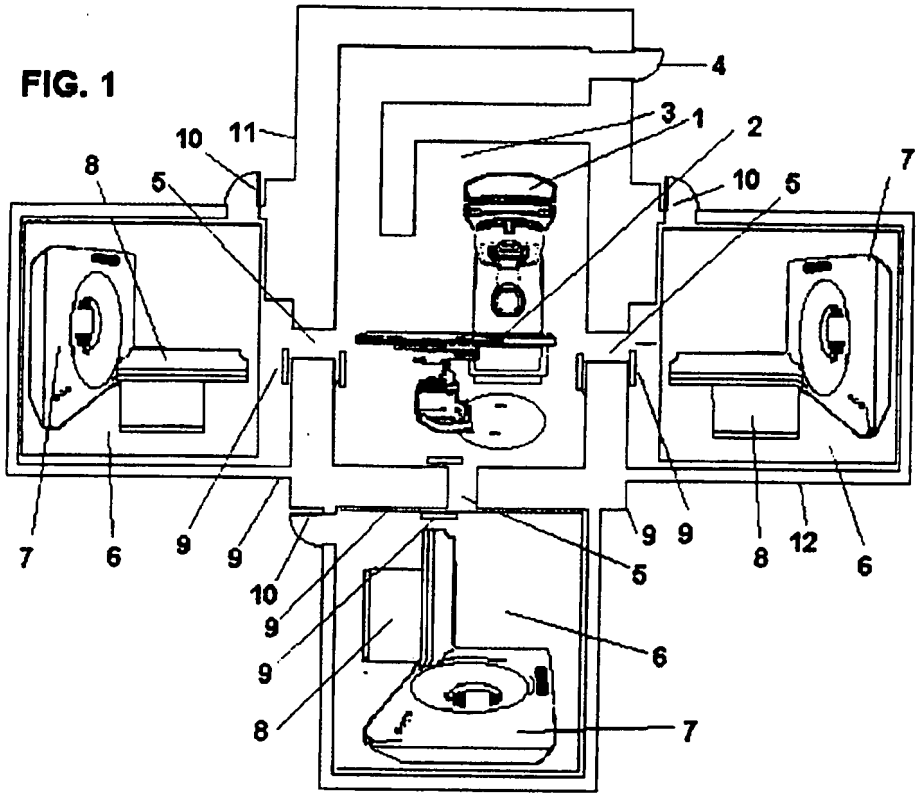
diagnostic imaging table as his own but is moved to the megavoltage treatment table on the same flat table top insert on which the imaging and the treatment verification is done.

25. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein precise target treatment site and its associated normal tissue with beam's eye view of dose distribution is assessed as in 3D conformal radiation therapy before treatment to obtain the maximum benefit of the treatment with no missing of the tumor and minimizing dose to the surrounding normal and critical structures and taking the advantage of the transfer of patient from the said diagnostic imaging table to the said megavoltage radiation therapy machine without the patient leaving the flat table top insert on which the patient is placed for isodose superimposed port verification imaging.

26. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein the routine treatment simulation and markings on the skin is done with the said diagnostic imaging device equipped with laser markers and with superimposed isodose distribution to the tumor site and to the surrounding normal tissue including to the critical structures and taking advantage of the transport system with the flat table top insert for the patient's transport from the said diagnostic imaging device's table to the megavoltage radiation therapy machine's table.

27. A megavoltage radiation therapy and diagnostic imaging system as defined in claim 1, wherein the said diagnostic imaging device is used as independent of the megavoltage radiation therapy machine for the routine diagnostic imaging of a Diagnostic Radiology Department when it is not used with the said megavoltage radiation therapy machine and thus the shared use of the said diagnostic imaging device by the Department of Radiation Oncology and the Department of Diagnostic Radiology.

FIG. 1



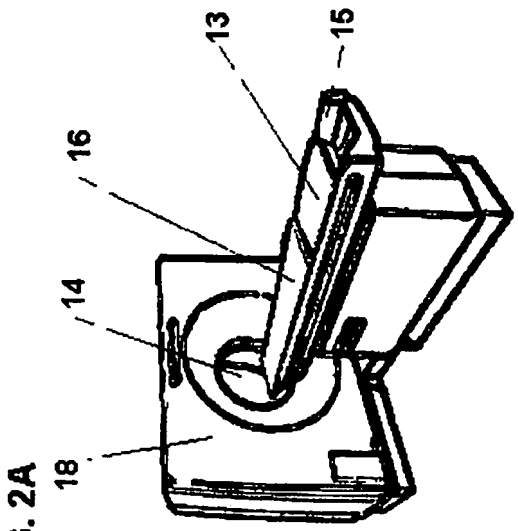


FIG. 2A

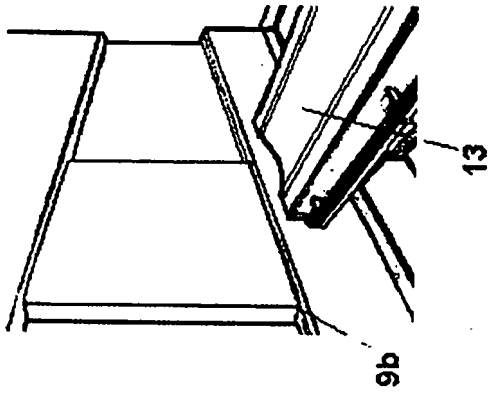


FIG. 2C

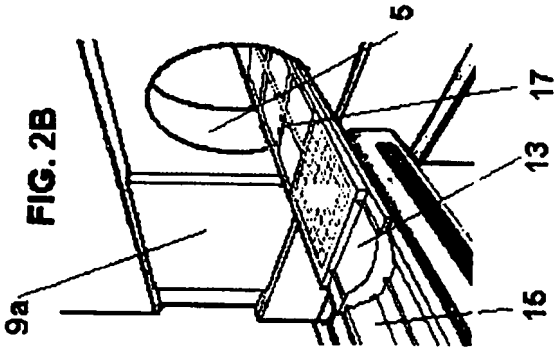


FIG. 2B

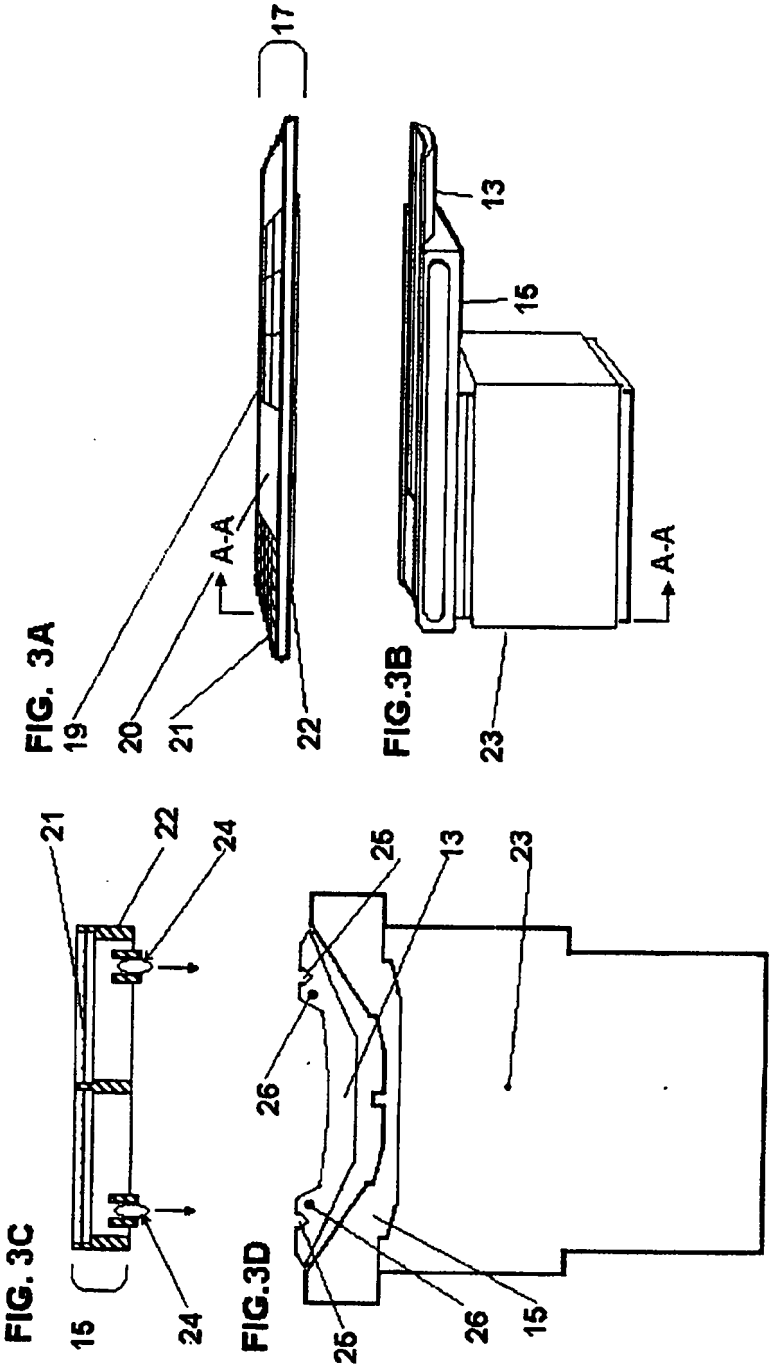

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FIG. 3A
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FIG. 3C
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FIG.3D

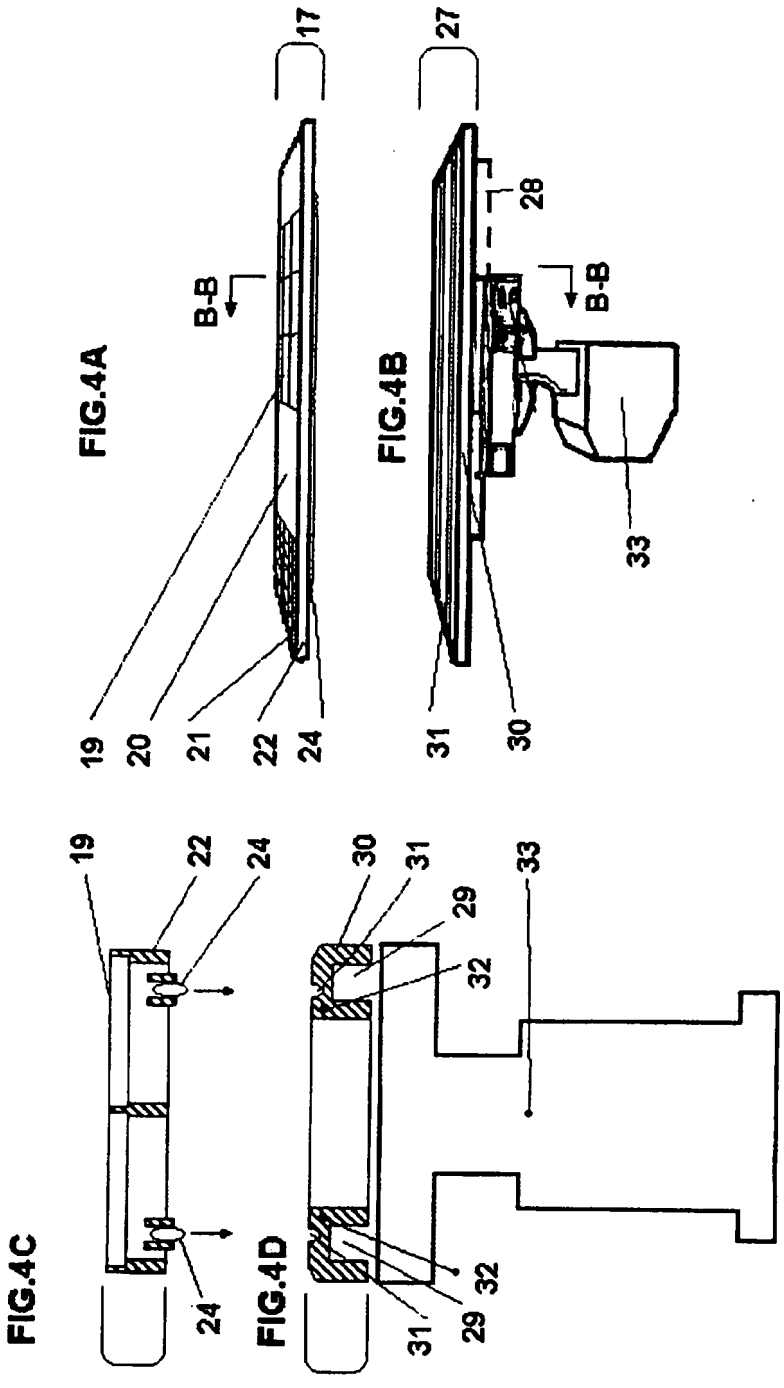
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FIG.4A
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FIG.4D

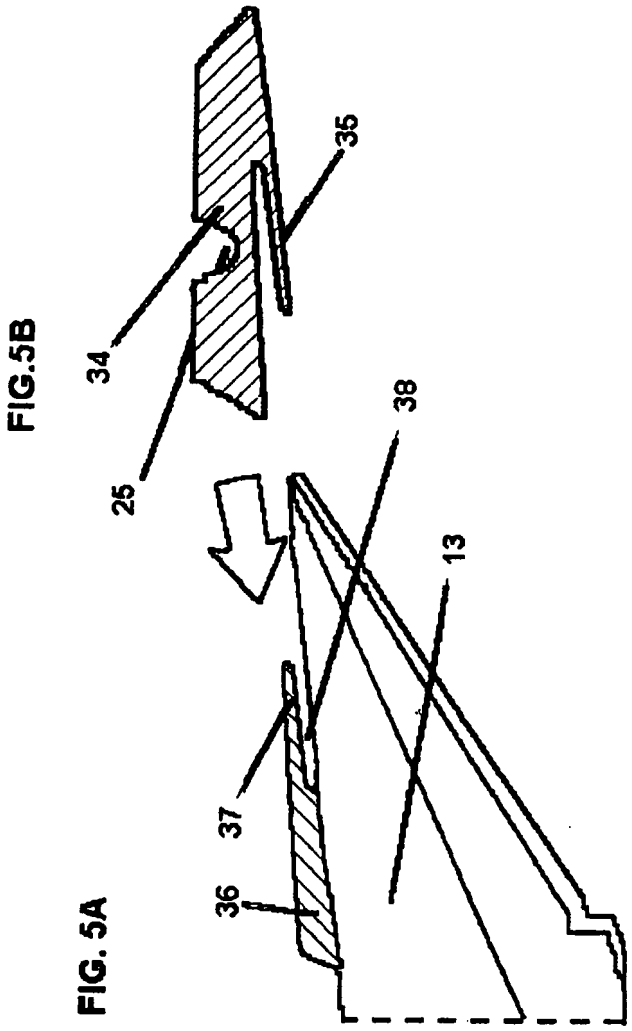

FIG.5B

FIG. 5A

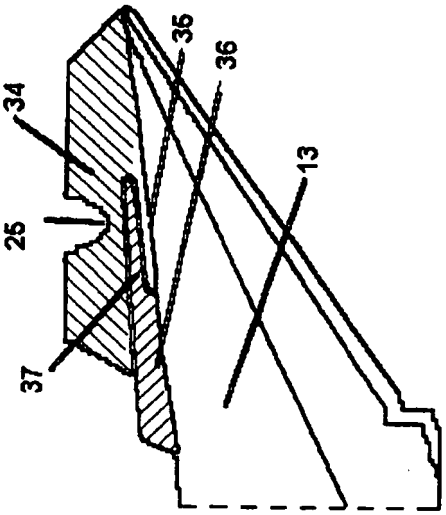

FIG. 5C

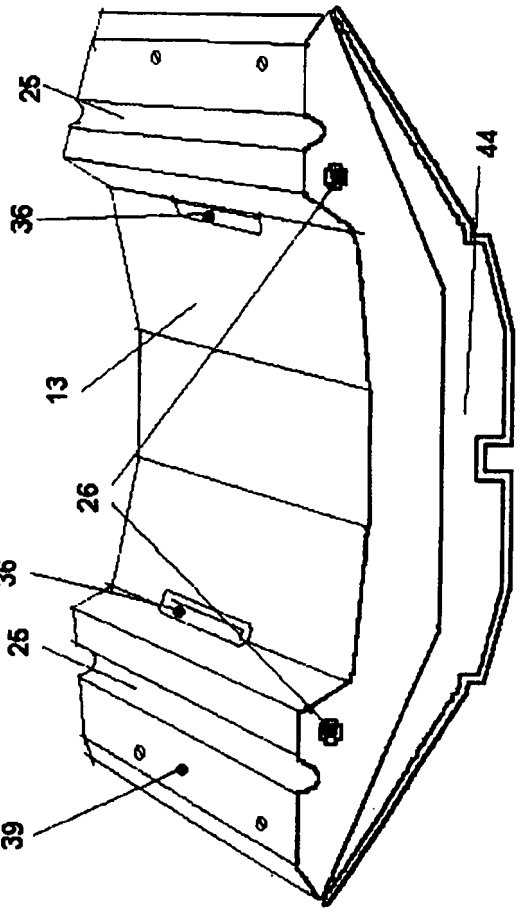

FIG. 5D

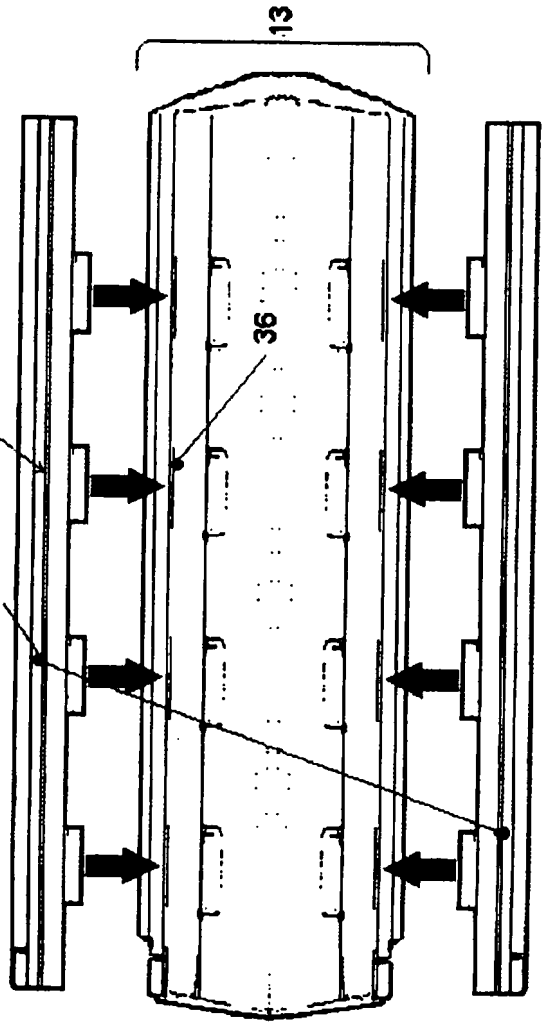

FIG. 6

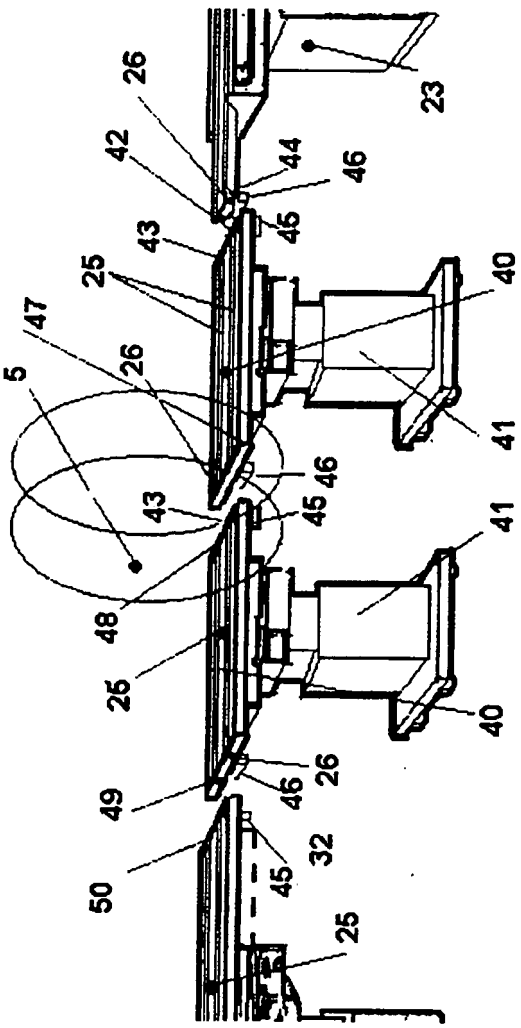
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FIG. 7

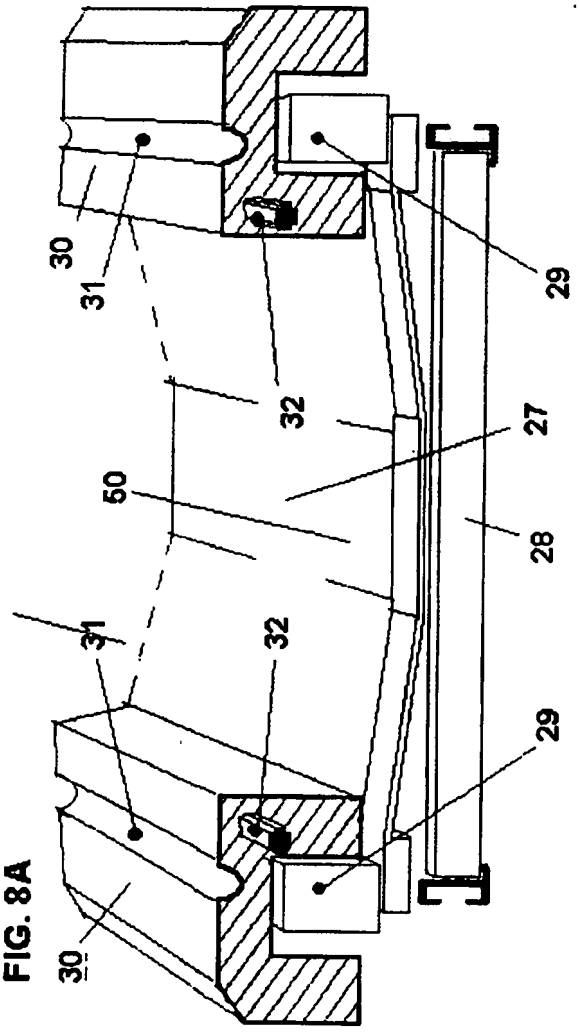


FIG. 8A

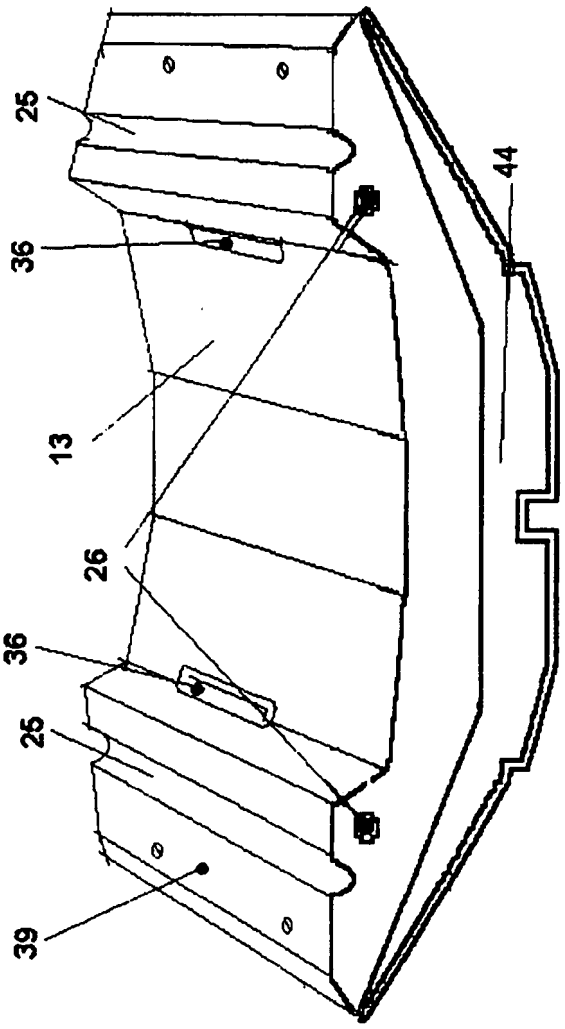


FIG. 8B

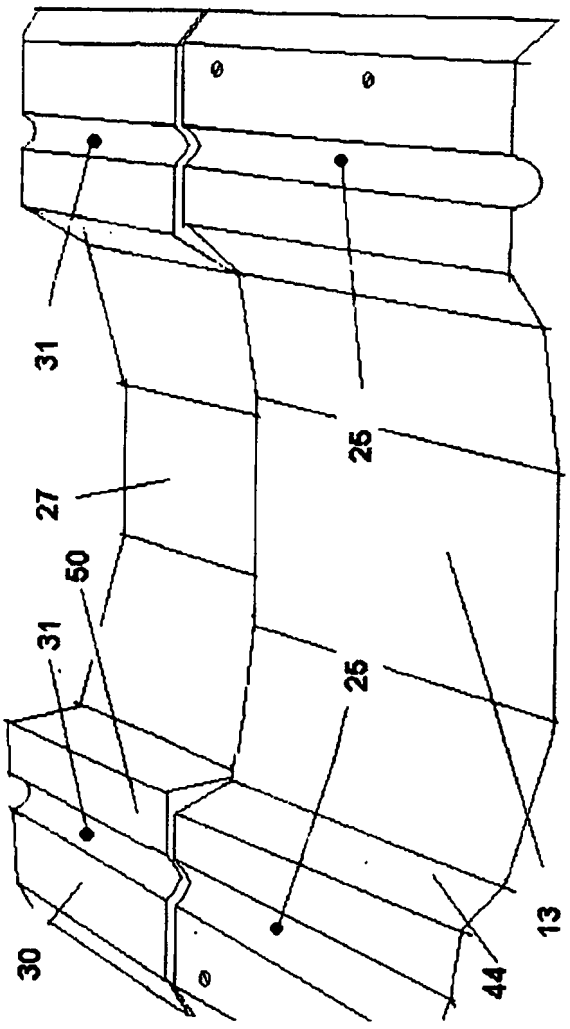


FIG. 8C

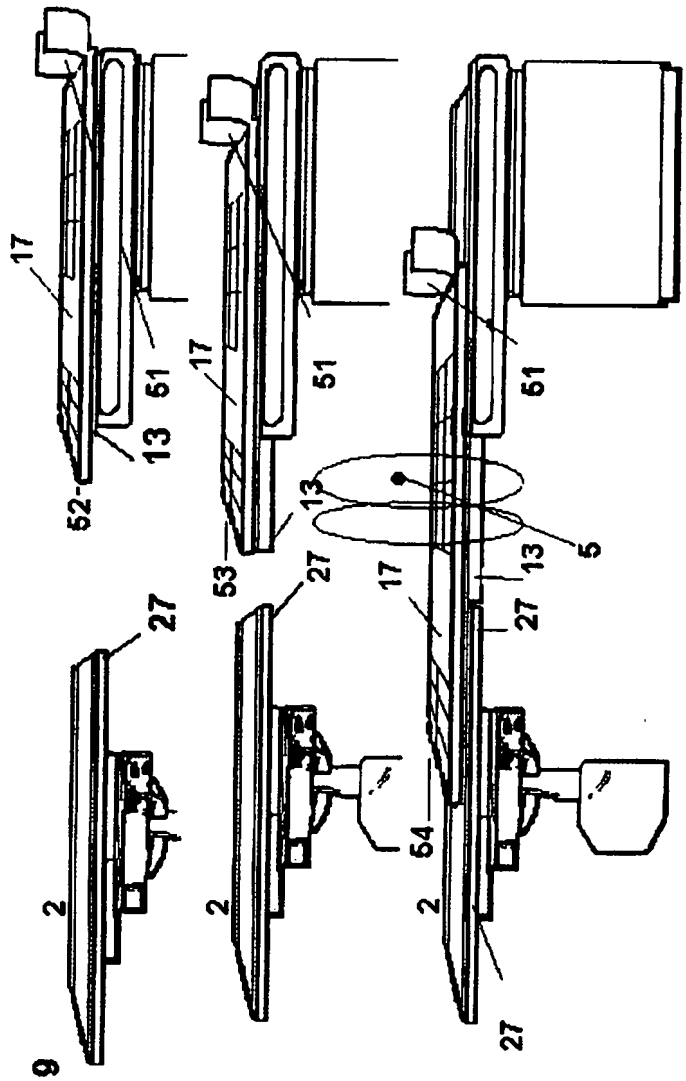


FIG. 9

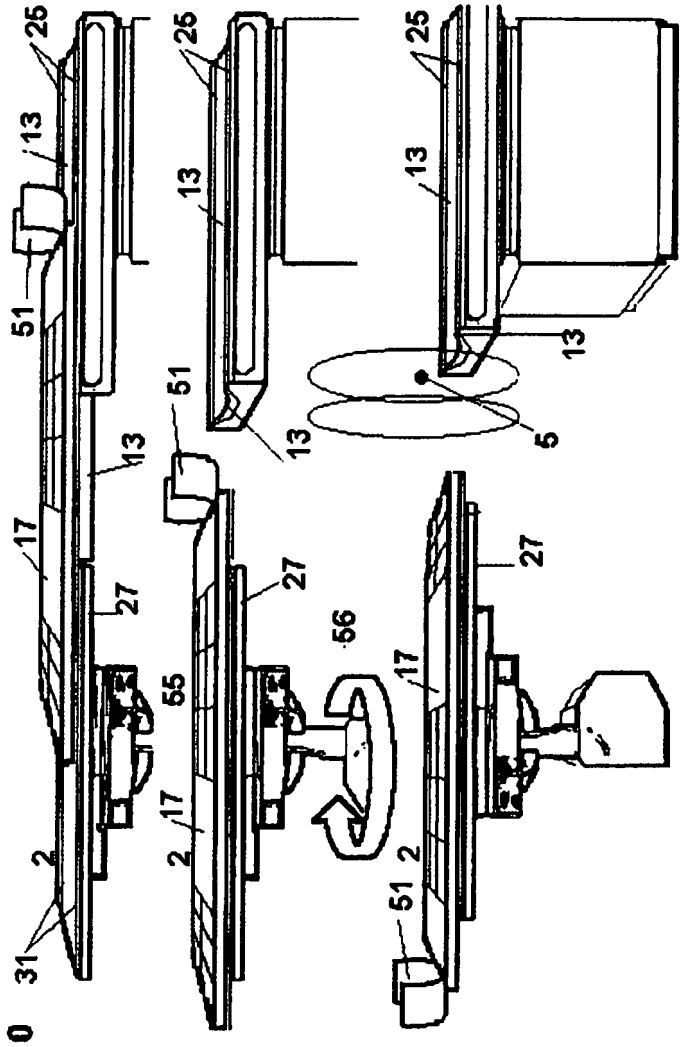


FIG.10

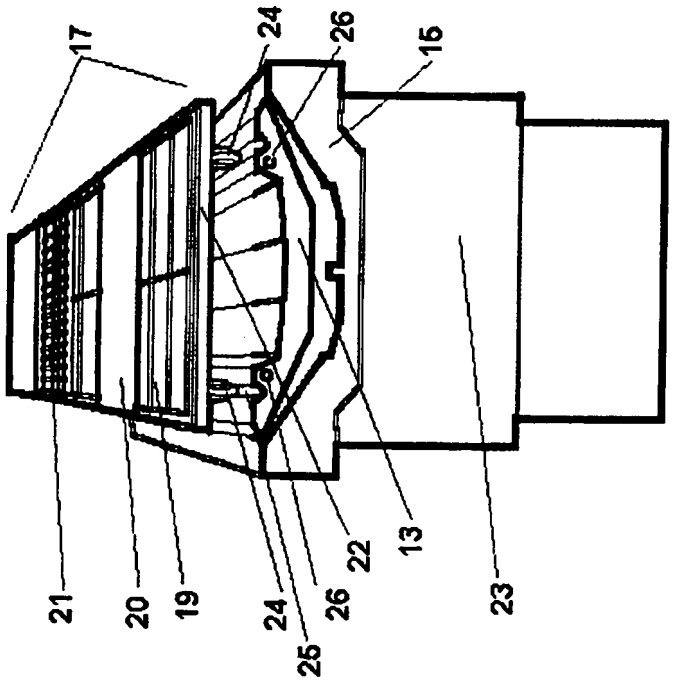


FIG.11A

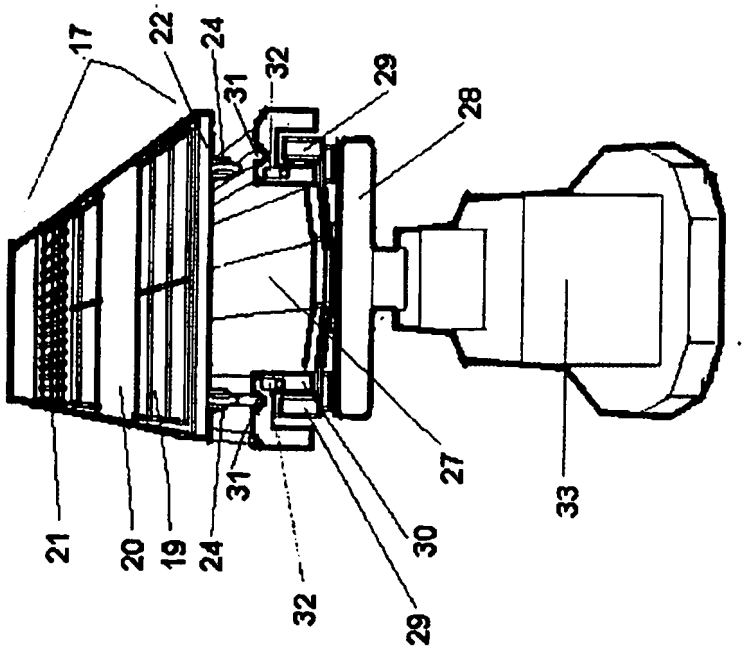
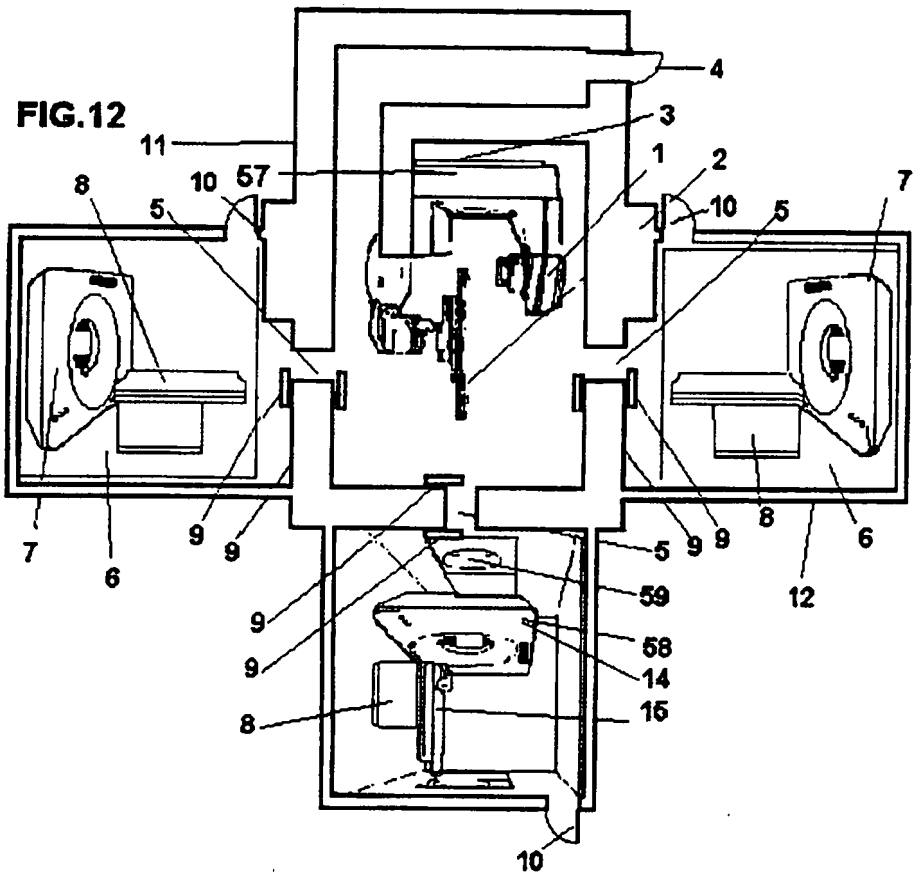


FIG.11B

FIG.12



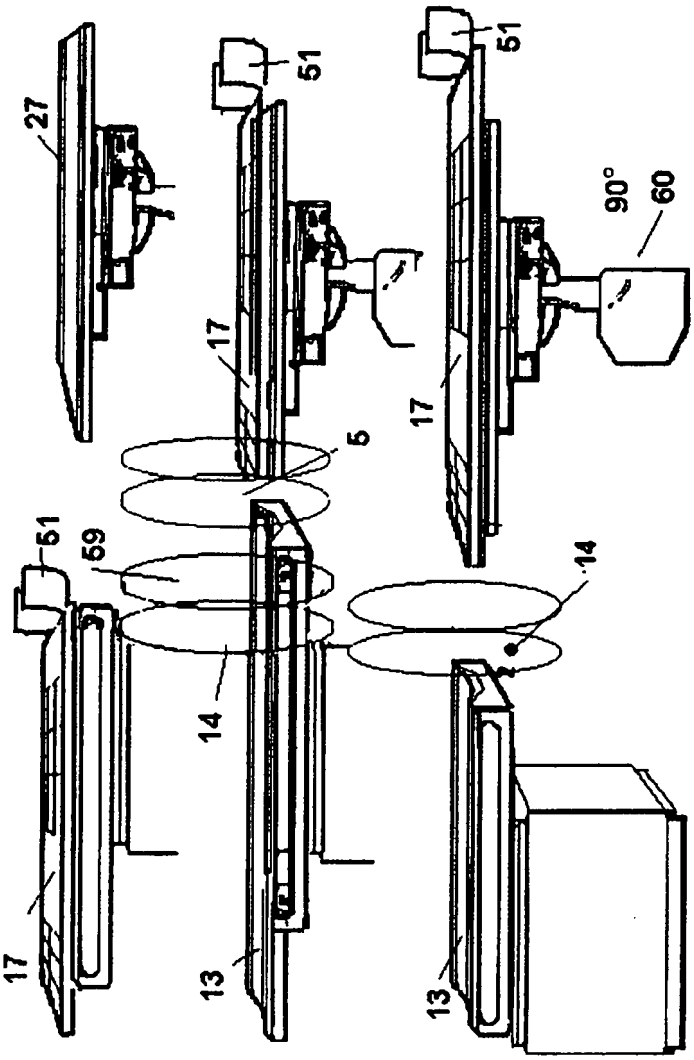


FIG.13

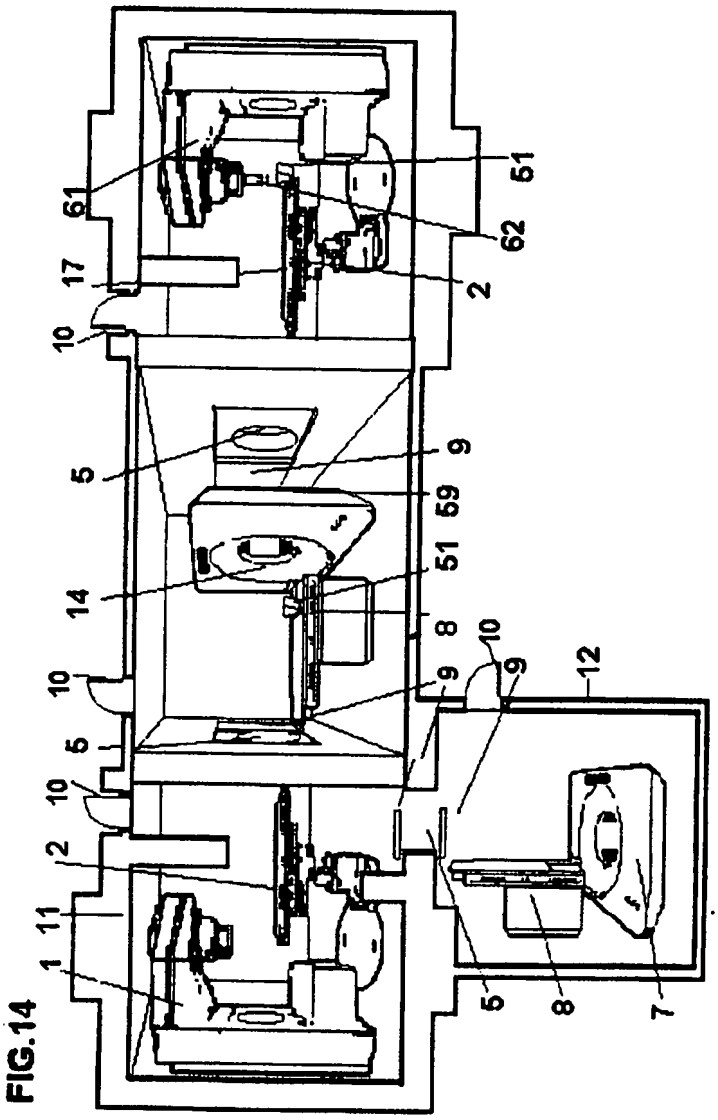


FIG.14

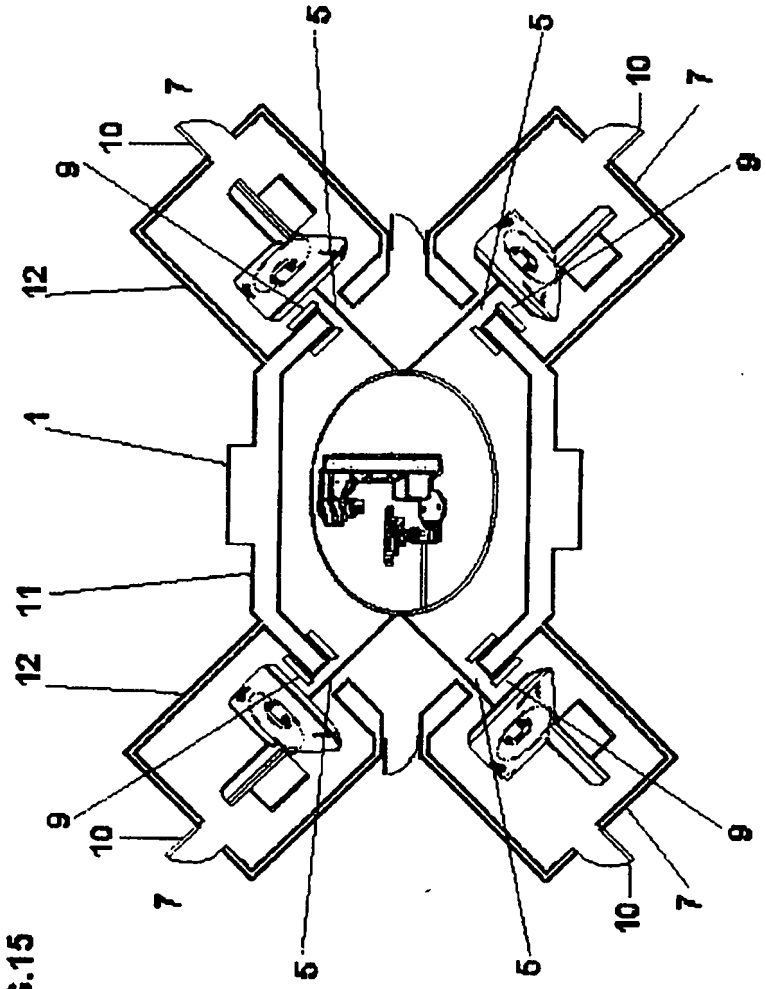


FIG.15

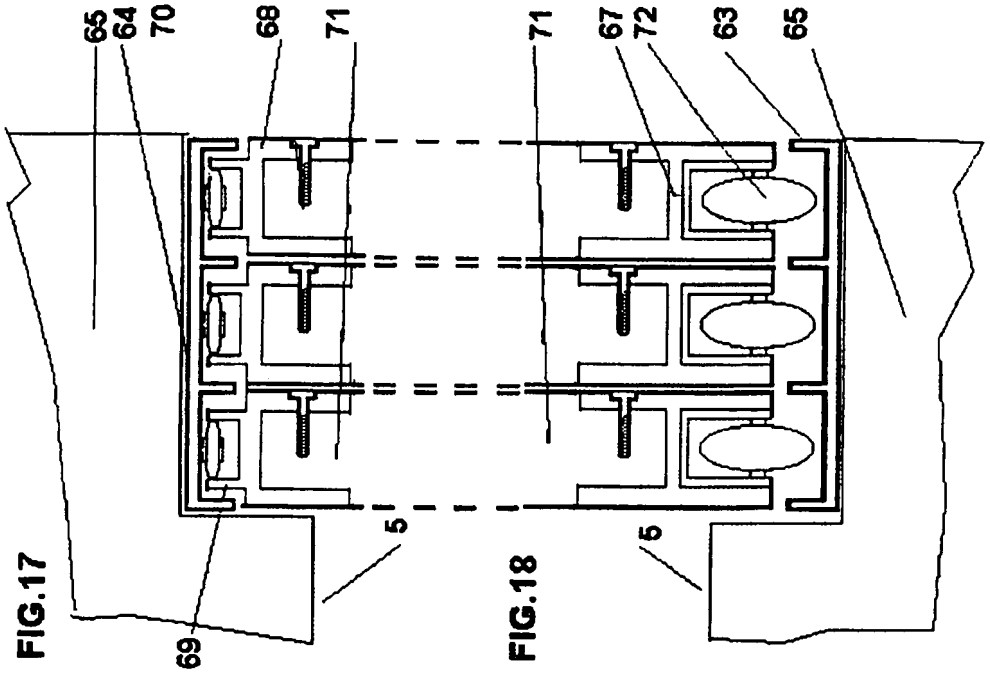


FIG.17

FIG.18

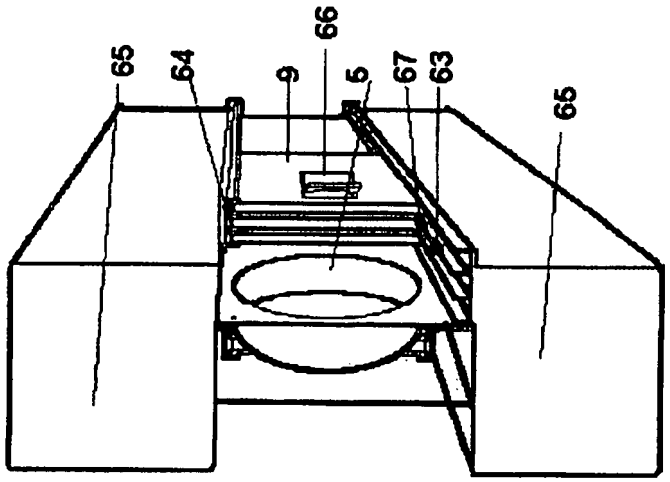


FIG. 16

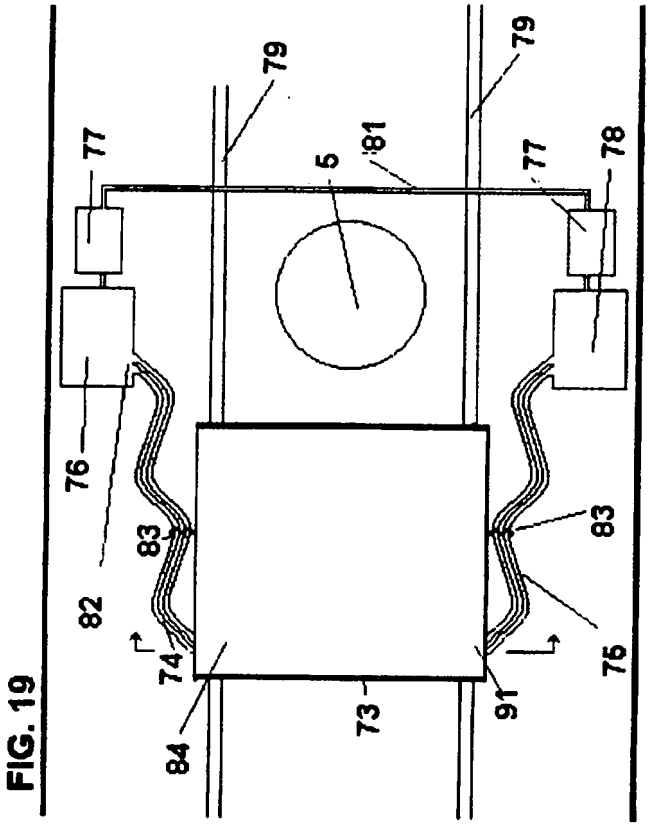


FIG. 19

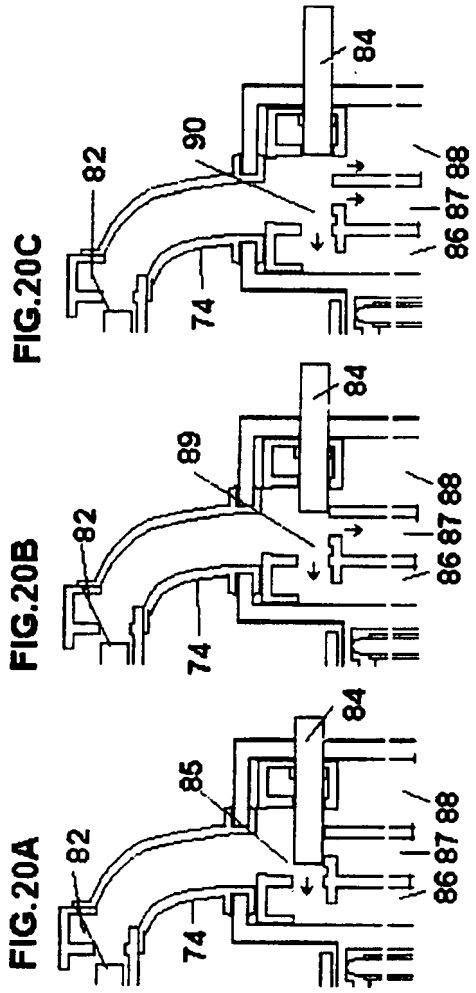


FIG.20C
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FIG.20B
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FIG.20A
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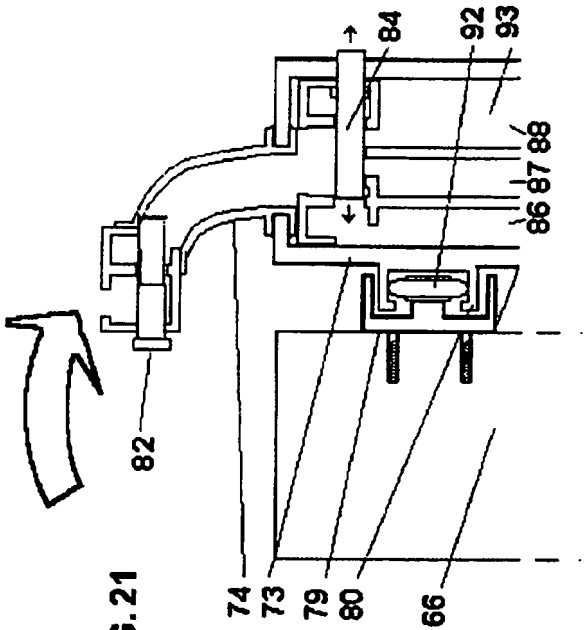

FIG. 21

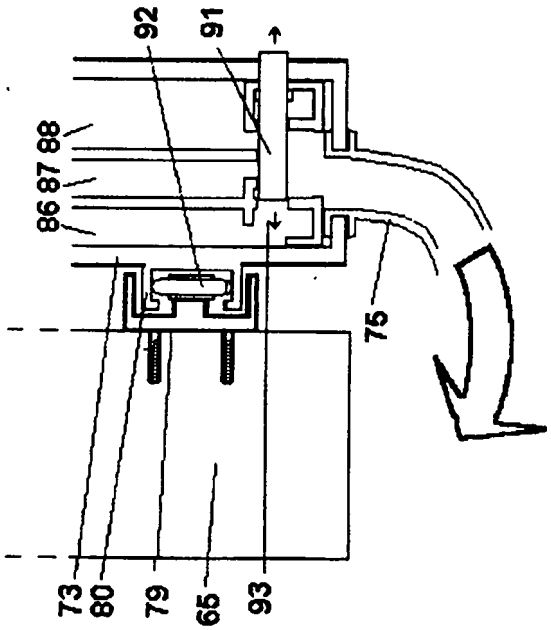

FIG. 22

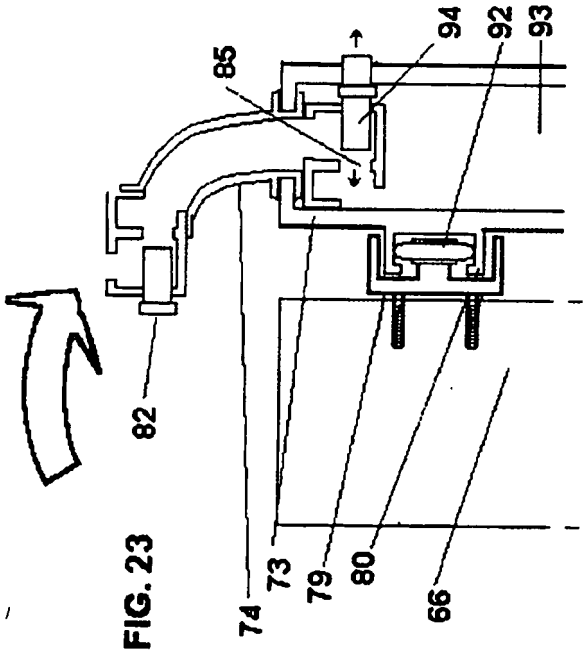

FIG. 23

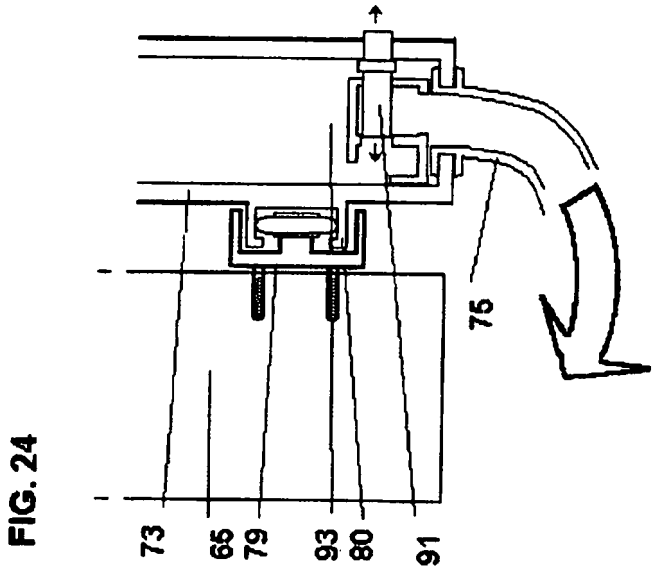

FIG. 24

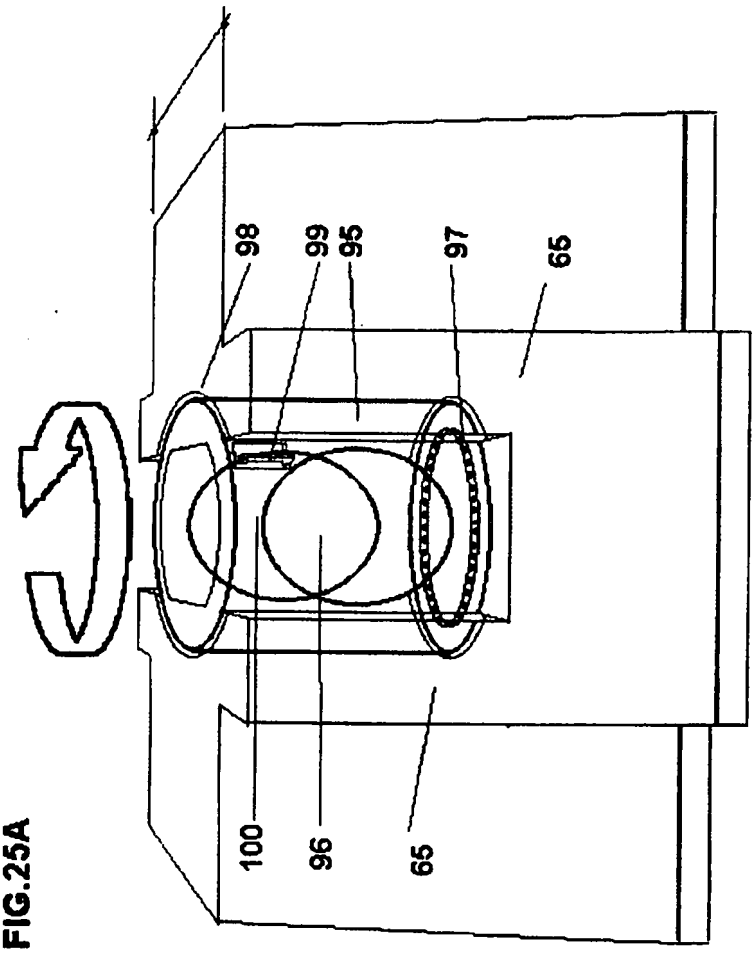

FIG.25A

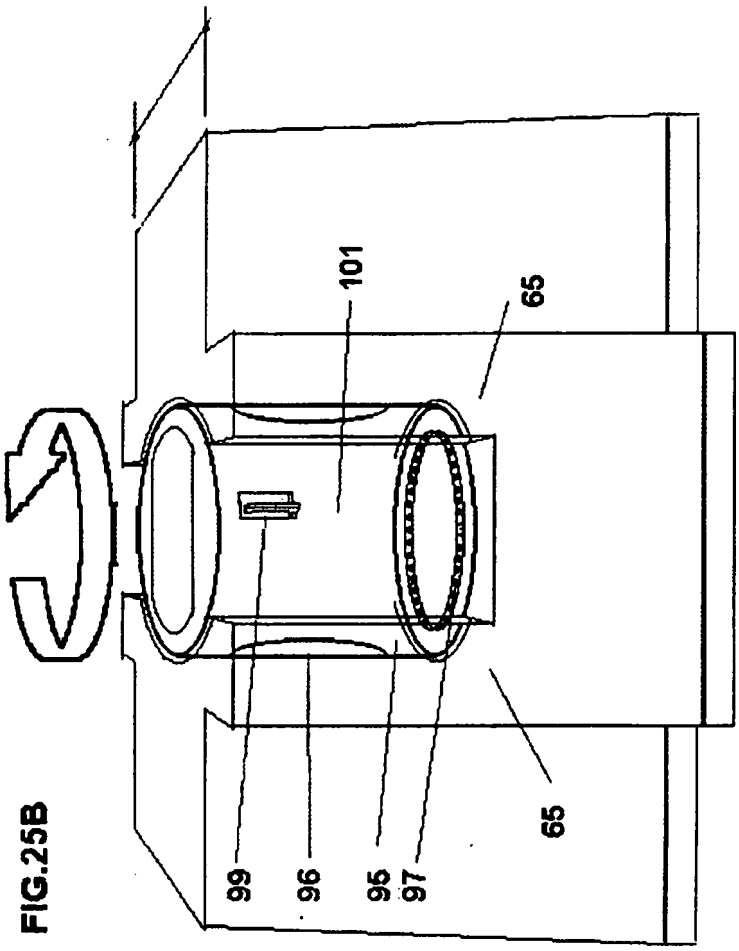

FIG.25B

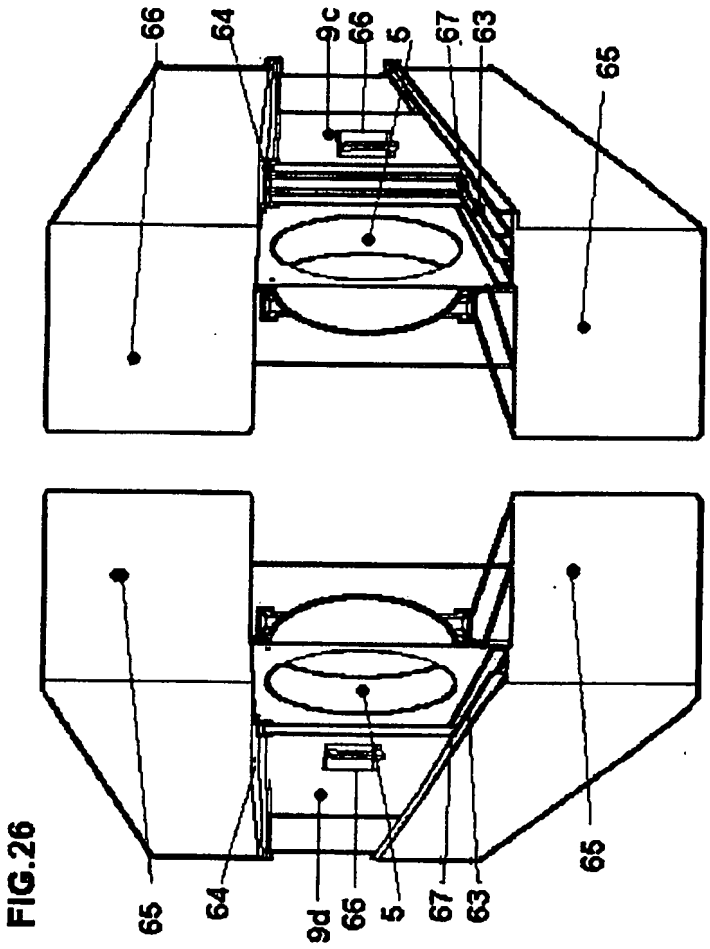

FIG.26

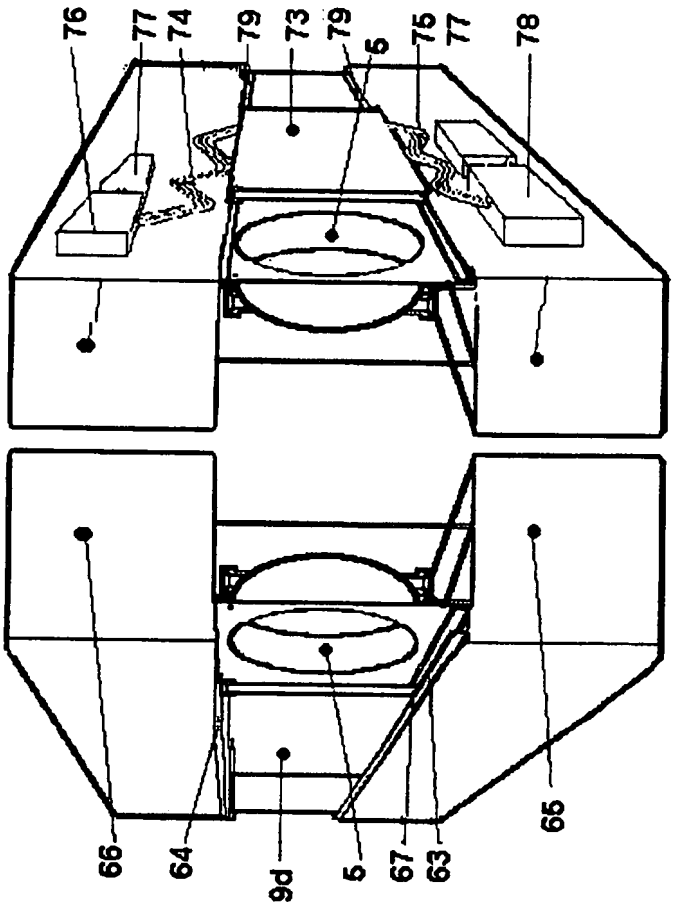

FIG. 27

FIG. 28

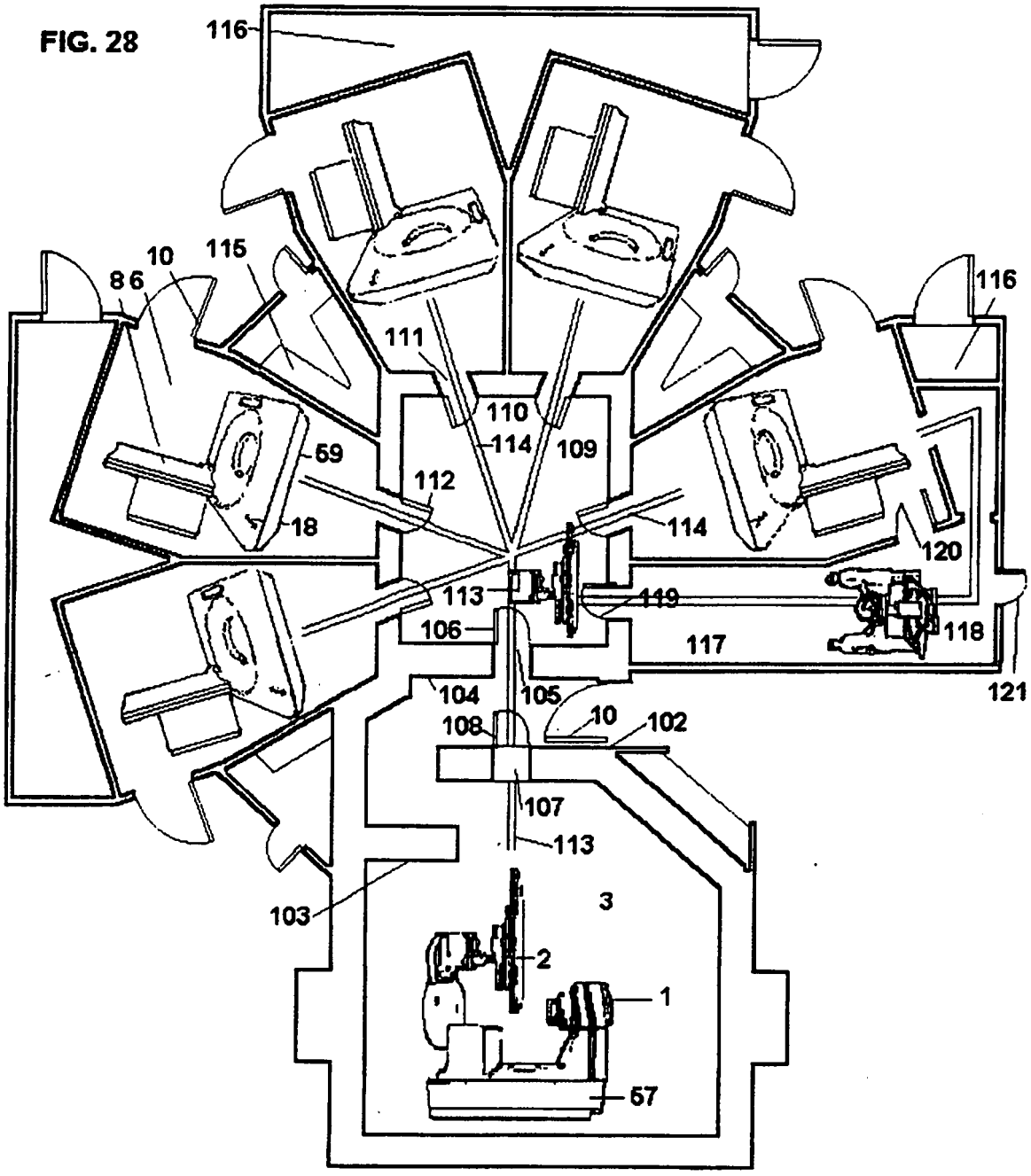
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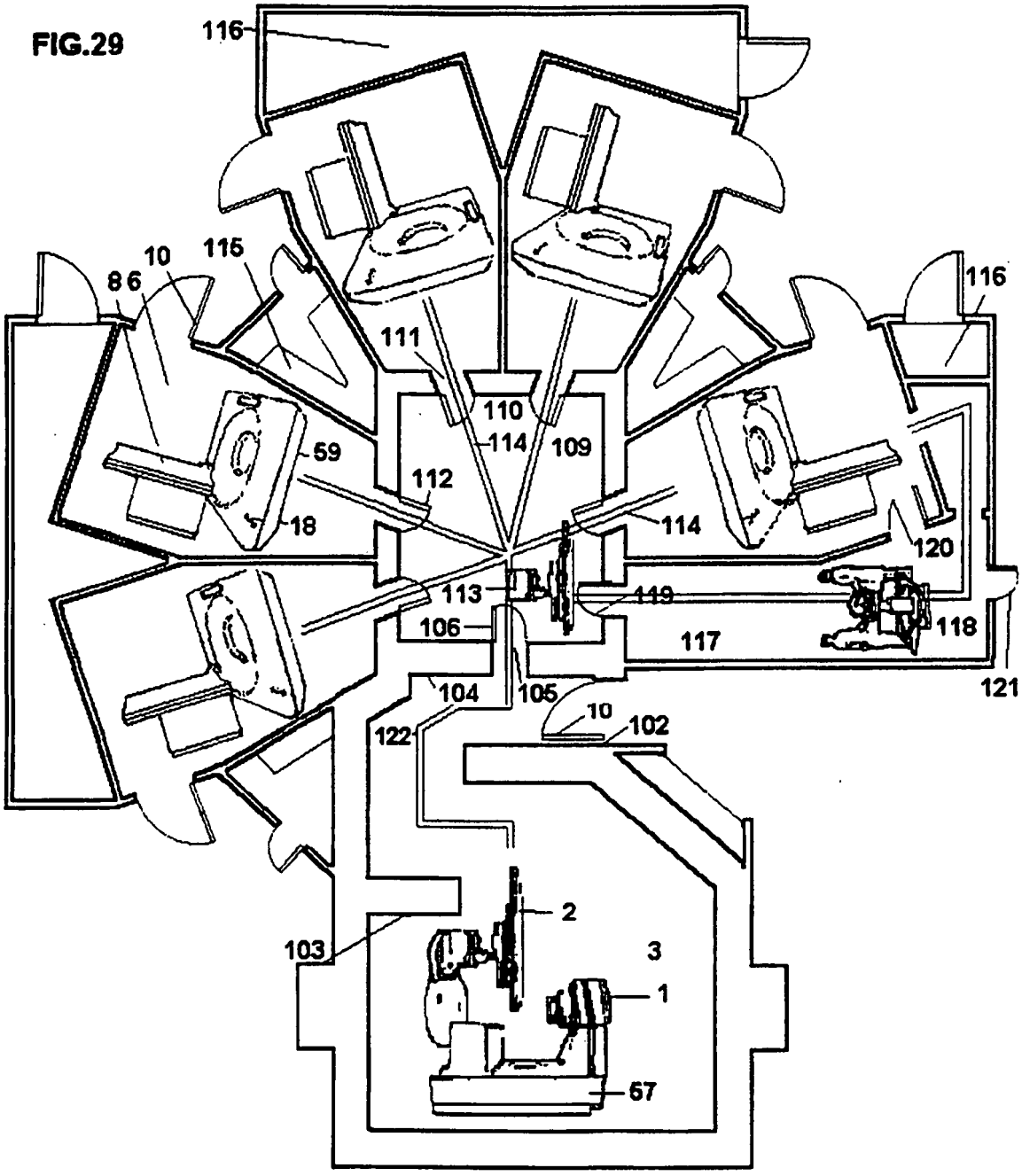
FIG.29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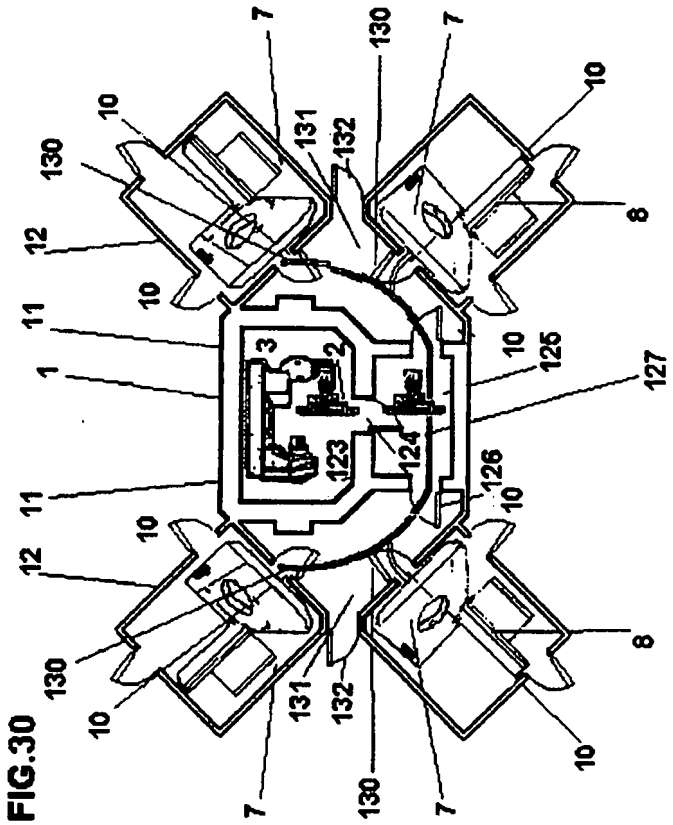
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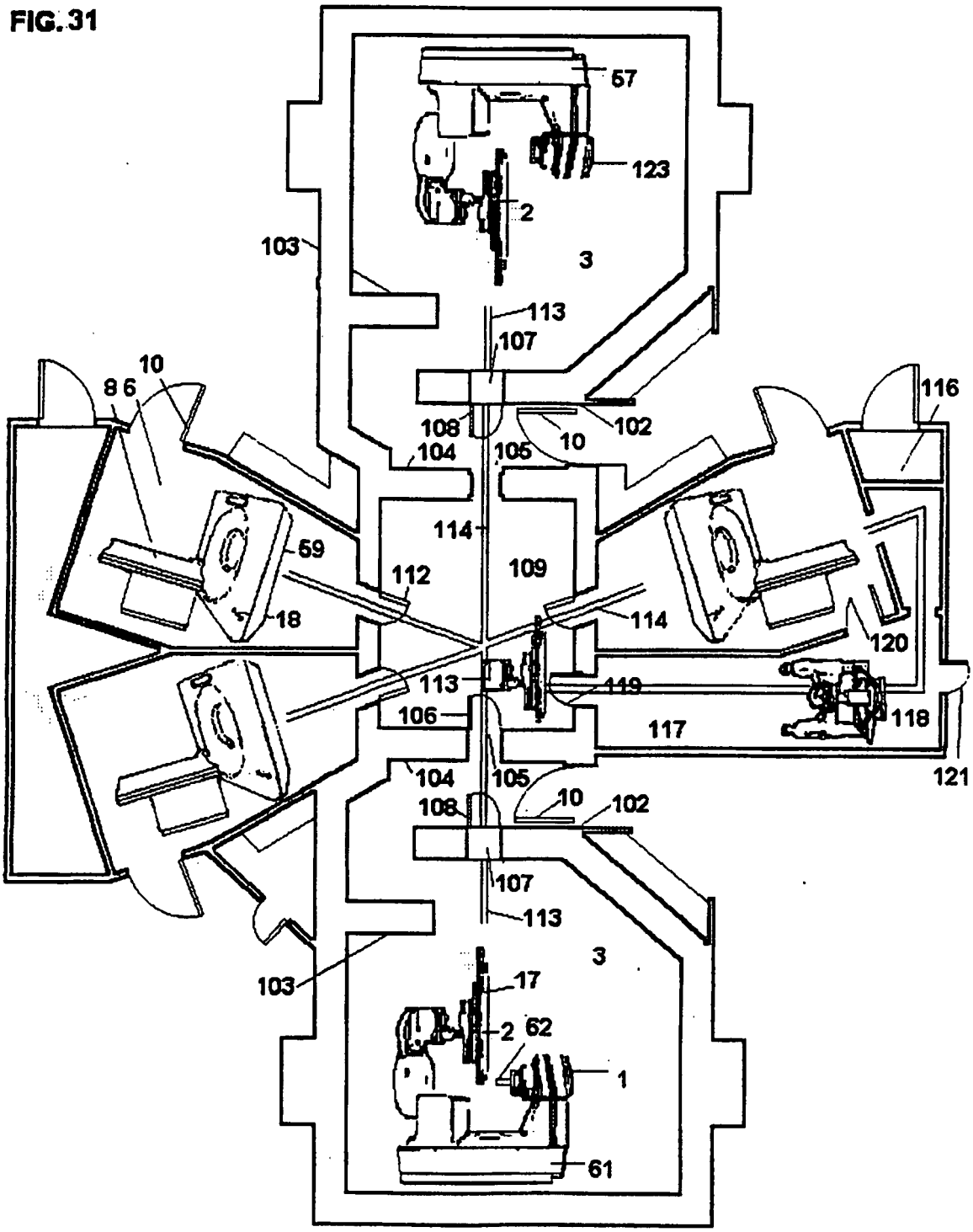
FIG.30

FIG. 31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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/14143

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A61B 5/00
US CL :128/653.1, 653.2; 364/413.13; 378/62-65
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 128/653.1, 653.2; 364/413.13; 378/62-65

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,537,452 A (SHEPHERD et al) 16 July 1996, abstract.	1-27
A	US 5,490,513 A (DAMADIAN et al) 13 February 1996, abstract.	1-27

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search	Date of mailing of the international search report
25 OCTOBER 1996	07 NOV 1996
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3590	Authorized officer Diane Smith for ELENI MANTIS MERCADER Telephone No. (703) 308-0899

Form PCT/ISA/210 (second sheet)(July 1992)*